PHASE II

PROGRESS REPORT

JANUARY 11, 1966

RESEARCH AND DEVELOPMENT FOR FABRICATING A TITANIUM GORE SEGMENT

NAS 8-20534

FACILITY FORM 602

N67-26286 (ACCESSION NUMBER)	(THRU)
45 (PAGES)	5 (CODE)
CR-84049 (NASA CR OR TMX OR AD NUMBER)	15 (CATEGORY)

Prepared for

George C. Marshall Space Flight Center

by

The Boeing Company
Aerospace Group
Space Division
Launch Systems Branch

NAS 8-20534 (6)

RP 7.44352

SUMMARY

This report covers a two-month period and the completion of Phase II of the contract. All the objectives of Phase II, Tooling and Manufacturing Plan, have been successfully accomplished. A design for a titanium (8Al-1Mo-1V) base gore segment has been completed. (SK-P1-1165-B applies.) This design satisfies all the requirements for the 2219-T87 aluminum gore segment shown in MSFC drawing 60B25206-1 (gore,base, lower head, fuel tank). A comparative weight analysis (titanium versus aluminum) shows a weight reduction of 24 percent when titanium is used.

All the tooling required for the titanium gore fabrication in Phase III of the contract has been completed. The Screed Tool used in fabricating the Vacuum Forming Tool and to be used in checking the contour of the formed gores has been completed. The Vacu-form Tool for forming the gores has been fabricated. The diffusion bonding tool developed and fabricated in Phase I is ready for use in Phase III. The flat pattern layout has been developed for the machining and trimming of the gore. The vacuum chuck for holding the titanium plate during machining is complete. The trim fixture for holding the formed gore during the trimming operation has been fabricated. Two 3-inch thick steel plates are available for flattening the titanium plate after the diffusion bonding operation. The Screed Tool and Vacu-forming Tool have been inspected by Quality Control.

Temperature check of the Vacu-form Tool showed that the tool would heat up to 1450° F within 1-1/2 hours and the die temperature could be controlled at 1450° F within a tolerance of $+ 75^{\circ}$ F and -25° F during a 1/2-hour soak period. A check of the cool down rate showed that a maximum of 100° F per hour could be maintained from 1450° F to 900° F.

The Manufacturing and Test Plan have been completed and are included as a part of this report.

Two 75 KVA power carts with controllers and recorders were purchased by Boeing to provide power for heating the Vacu-form Tool. A third power cart is available within the Company, so all the facilities required are presently on hand.

A series of 35 mm color slides have been taken of the Vacu-form tool construction and have been forwarded by separate correspondence.

All materials are available except the titanium plates, all tools are in readiness, and all plans are set for go-ahead for the third and final Phase III of the contract. Some difficulty has been experienced with the titanium plate supplier. In the rolling operation micro cracks appeared on the surface of the plate when it was rolled to a thickness of 2 1/2-inches. Negotiations are being made with the supplier to determine if the plates can be salvaged, or will require replacement. The start of Phase III will depend upon the outcome of these negotiations.

OVERALL PROGRESS - PHASE II

I. Design of Gore

At the conclusion of Phase I, a titanium gore design drawing SK-P1-1165-A was submitted to NASA for review. During Phase II, the design was improved by eliminating unnecessary weight, and a new drawing SK-P1-1165-B was approved by NASA. The primary changes in the new drawing were increasing the number of merdional ribs from 4 to 6, decreasing the width of the ribs, and decreasing the width of the weld lands. The net result of the changes has reduced the weight of the titanium gore from 220 to 210 pounds, which represents a total weight reduction of 24 percent over the aluminum gore. The existing aluminum gore weight is 276 pounds.

II. Tooling

All tooling has been completed and is ready for part fabrication in Phase III. The tooling consists of the following items:

1. Vacu-form tool fabrication and proof testing
2. Screed tool fabrication and inspection
3. Vacuum chuck
4. Trim fixture
5. Hot flattening tool
6. Diaphragm
7. Diffusion bonding tool
8. Flat pattern development

A description of the fabrication and purpose of the above tooling is given below. Where applicable inspection and test procedures of the tooling are described.

Vacu-form Tool Fabrication

Tool designs are available for both the Vacu-form tool and the Screed tool. The Screed tool was used to make the forming tool. See Figure 1 for a cut-away of the forming tool.

The Vacu-form tool was fabricated in four major steps as follows:

1. The concrete base was cast on the factory floor. It contained sufficient steel for re-inforcement and for attachment to the steel box.
2. The steel box was welded together and was also attached to the cement base by welding.
3. In adding the internal structure to the steel box, the Screed tool was very helpful in maintaining control of the contour and buildup of each layer of material. The Screed tool could be swung to any location for checking. The fabrication sequence of the internal structure of the steel box was as follows:
   a. Conventional fire brick was cemented in place to within 6 inches of the final contour. The last layer of bricks were band sawed when required to obtain the general gore configuration. Figures 2 and 3 show laying of the fire brick and use of the Screed tool for checking brick placement.
   b. The fire brick surface was covered with a castable cement and screeded to contour with the Screed tool. Figure 4 shows the Screed tool being used to check the contour of the first Glasrock blocks placed on the castable cement which was screeded to contour by the Screed tool.
   c. The Glasrock blocks (50-pound density, 4-1/2 by 18 by 18 inches) were cemented to the castable cement surface. See Figure 4.
   d. Ten wax* covered end edge heater tubes were cemented in place at either end of the tool. Figure 5 shows one end of the die, and the location of the 10 edge heater tubes. Both ends are the same and the end heaters are below the main heaters.
   e. A 1/2-inch layer of Glasrock cement was screeded over the Glasrock blocks with the use of the Screed tool.

*Sheet of wax (0.020 thick) are layed up on the tubes before the tubes are placed in the tool. This wax will burn out when the tool is "fired" leaving space for tube expansion.

f. 140 wax* covered tubes were located in the die at a spacing of 0.75 inch, centerline measurement. Figure 6 shows the main heater tubes tacked in place by cement.

g. The finished surface was made by screeding a 3/8-inch coating of Glasrock cement over the top of the tubular heating elements. Figure 7 shows the heated area of the die with the finished surface. Both ends and sides are still open.

The final surface before heatup was inspected by Quality Control and waviness was found to vary less than 0.010-inches in any 6-inch area. The contour of the die was within $\pm$ 0.050-inches of nominal and the radius of the die was within $\pm$ 0.080-inches of nominal.

4. The electrical hookup of the die included the following items:

a. Steel braid with provisions at each end for welding was used to connect the tubular heating elements to each other in groups of ten to a zone. Figure 8 shows heating elements connections at one end of the die. In turn each zone of 10 heating elements was connected to a bus bar that ran through a hole in the steel box. The bus bar was protected where it ran through the steel box by a rubber insulator.

b. The bus bars were bolted to wire leads on the outside of the tool. These wire leads in turn were connected to the three 75 KVA power carts. Figure 9 shows the terminal box in the foreground for connection of the power from the power carts to the die. The small diameter white wire is the thermocouple wire being connected from the power carts to the die. Figure 10 shows the (3) 75 KVA power carts in the background. The men in the photo are closing in one end of the die with fire brick and a covering of Glasrock cement.

c. In construction of the Vacu-form tool, provisions were made for the use of 34 thermocouples for controlling and recording die temperatures. The 34 thermocouples were installed, calibrated, and connected to the power carts. A controlling recording thermocouple was in each of the 16 zones plus 14 recording only thermocouples were in all zones except the 2 end zones. Four additional recording only thermocouples were located in the area of part corner location. See Figure 11 for thermocouple locations.

d. After all electrical connections were completed, an electrical continuity check was made which showed there was good continuity.

e. The power was turned on, and the tool was heated to 200° F for 8 hours. During this period, the wax on the heated elements melted and created a lot of smoke. Also, there were numerous small jets of flame emitting from the ends of the tubular heating elements. The flames were caused by the wax vaporizing. Although the smoke and flames were spectacular, they caused no damage. The heating of the die also forced out a considerable amount of moisture.

f. After 8 hours of heating at 200° F, the die was allowed to heat up to 1000° F to further bake out the die. The die was allowed to cool to room temperature, and it was noted that surface cracking was insignificant.

g. Because the heating elements are of different length, the power carts had to be adjusted to increase the voltage in the longer heating elements. The voltage ranges from 200 for the short tubes to 300 for the longest tubes.

h. After the voltages had been regulated, the tool was heated to 1200° F. All 16 zones were set at 1200° F, and this temperature was reached in 50 minutes. The die was covered with one thickness of asbestos cloth to retain the heat.

Proof Testing of Vacu-Form Tool

The preliminary testing accomplished above assured us that the tool would meet the design requirements of heating a part to 1450° F in

1-1/2 hours. Therefore, we proceeded to close in the electrical hook-up at either end of the die with fire brick and cement. The vacuum pump was connected and preparations were made for a complete test minus the actual part.

The following are the steps that were performed:

1. Strips of silicon rubber 0.125-inch thick and 3 inches wide were placed on the die flange.
2. The stainless steel diaphragm, 0.020 by 144 by 228 inches, was placed over the die and secured to the die flange with large "C" clamps.
3. A 1/2-inch thick covering of micro quartz insulation sheeting was placed on the diaphragm covering the heated portion of the die.
4. The power was turned on and the power cart controllers were set at 1450° F. The recorder was put in operation to record the temperature and time.
5. The vacuum pump was connected to the die and put in operation at the same time the heating was started.
6. There were numerous leaks, especially at the diaphragm seal. Although we continued to plug the leaks, we could not get a vacuum of over 8 inches of Hg. At this point we couldn't tell whether the pump, die leaks, or a break in the diaphragm was the problem.
7. We continued the heatup and were able to obtain 1450° F in 1-1/2 hours. Figure 12 shows time at temperature curve. A cool down cycle was not run because of the vacuum failure. After the test and the insulation was removed from the diaphragm, it was observed there was a break in the diaphragm about 18 inches long. The break was in the heat affected zone of a weld. We are positive that this diaphragm problem can be solved and will solve the problem in the interlude between Phase II and III of the contract.

To determine if the die was capable of having a vacuum pulled and that the pump was capable, another test was run using a vinyl plastic sheet as a diaphragm. A 40-mil thick vinyl sheet was layed over the die with the die at room temperature. The vacuum pump was started, and in 5 minutes we had a vacuum of 25 inches of Hg. This test proved that the die was capable of holding a vacuum and the pump was adequate. After running the vacuum for 30 minutes, the vacuum indicator showed a vacuum of 26 inches of Hg. Our previous tests have shown that a vacuum of 25 inches of Hg is adequate for the forming operation. Figure 13 shows the completed vacu-form die with the vinyl sheet in place during a vacuum test. Figure 14 is a close up view of the vacuum pump and the vacuum meter indicated almost 26 inches of Hg being pulled.

A further heating test of the die was made for the complete heat cycle. A layer of micro quartz blanket insulation was placed covering the complete die. The time was noted and the power was started. A continuous recording was made during the complete cycle. The temperature of the die reached 1450° F in 1-1/2 hours. The die was allowed to soak at this temperature 1/2 hour. After the soak period, the die was cooled to 900° F at a rate of a maximum of 100° F/hour. The insulation was left in place during the cool down. Every hour we reset the power cart's controls 100° F lower, except the last hour where it was set 50° F lower to 900° F. During each hour, the power would automatically come back on if the rate exceeded 100° F which was the case during the whole cool down cycle. Even though we did not have a part in the die, and we did not use a diaphragm in this test, it is our opinion that outside cooling will not be necessary during a part forming run. See Figures 15 and 16 for the heatup and cool down cycle of the die.

<u>Screed Tool, Drawing FMIT 12R17260 Fabrication</u>

The function of the Screed tool was to provide a means of controlling the contour of the Vacu-form tool at the various levels of construction.

Figure 17 shows the Screed tool and its relationship to the Vacu-form die. The Screed can be held in any position in relation to the die for checking or can be used to sweeep-in or screed a cement surface. The proper thickness of each layer of material is maintained with the use of the Screed tool. Governing the thickness of the different layers of materials is important in providing a uniform heat distribution in the die surface. The Screed tool also provides a means of inspecting the final contour of the Vacu-form die and gore segment. The critical features of the Screed tool in the inspection function is the template contour and its relationship to the sweep of the Screed arm.

The construction steps of the Screed tool are as follows:

1. A 16-inch diameter steel pipe, 9 feet long was welded to a steel base plate 1 by 48 x 48 inches. This is the stanchion assembly.
2. The bearing-holding structure was then mounted on the top plate of the stanchion assembly and temporarily bolted in place.
3. The Screed arm assembly consists of a steel pipe 10 inches in dimaeter and 19 feet long which has a provision at its midpoint for attaching to the bearing-holding-structure. To the lower end of the Screed arm, the near end of the Screed blade is attached so as to provide a gore configuration contour to the surface of the Vacu-form tool when the arm is swept through its arc. The upper half of the Screed arm only provides a counter-balance. A 3-inch diameter steel tube is attached to the far end of the Screed blade and the Screed arm as a brace.

When the Screed tool was completed, it was placed in its correct relationship to the Vacu-form tool and welded to it. The Screed tool template and its relationship to the Screed tool sweep were inspected by Quality Control before the Vacu-form die contour was inspected.

Inspection

The method of inspection of the Screed tool and the results are described below.

Detailed inspection procedure for checking the Screed tool and subsequently the Vacu-form tool are shown in Figure 18 and described below.

1. Set Screed to the center line of "x" and "y" (center of rotation shaft) by means of a transit and two tooling balls on the shaft holder.
2. Determined the angle of the shaft from a horizontal plane using a level and two reference tooling balls.
3. Located a reference tooling button on the support post and noted distance from lower tooling ball.
4. Located mylar template (furnished by Q.C. Numerical Control) to the Screed. This is accomplished by "miking" with inside micrometer from the shaft to the coordination point (118.811) marked on the mylar.
5. Checked the horizontal height of the marked coordination point on each end of the mylar with a level.
6. Checked contour of the Screed to the mylar.
7. Checked contour of the die to the screed and mylar; removed screed and mylar.
8. Attached a dial indicator to the sweep and moved sweep to E.O.P. and checked contour variations. Set indicator to a minimum of five different places.
9. The inspection determined that the Screed is located properly to the point of rotation, contour of screed is correct, and the contour of the Vacu-form die matches the screed.

The results of the Vacu-form tool are as follows:

1. Waviness of the die does not vary more than 0.010-inches in any 6-inch area.
2. Contour of the die is with $\pm$ 0.050 inches of nominal.
3. Radius of the die is within $\pm$ 0.080 inches of nominal.

Vacuum Chuck

A vacuum chuck is required to hold the titanium plate during the machining operation. A vacuum chuck approximately 4 by 7 feet is available, so we fabricated another chuck the same size. This gives us a chuck 4 by 14 feet. Our machine equipment will not accommodate a chuck any larger than this. Therefore, the machining operation will be accomplished in two steps, one-half the part at a time. The vacuum chuck was fabricated with our funds, so will remain the property of The Boeing Company.

Trim Fixture

A trim fixture of egg-crate design was fabricated from plywood. The fixture has the function of holding the formed gore segment during the trim operation and the finish boring of the 6.00-inch diameter hole. Our original plan was to use a skate attachment for the final trim of the part. However, a quicker and more economical method involving friction sawing with a skill saw is to be used. The sawing operation will be followed by belt sanding to finish the edge.

Hot Flattening Tool

One of the first operations on the titanium plate for the gore segment is to cut the 5.50-inch hole in the plate and diffusion bond the reinforcement ring around the hole. The diffusion bonding operation will cause distortion in the plate. Hot flattening in a furnace at 1200° F for two hours will remove distortion in the titanium plate caused by the diffusion bonding and mill rolling. After flattening, the titanium plates will be ready for machining.

Each titanium plate will be sandwiched between two mild steel plates and thermal cycled in a furnace. The weight of the mild steel causes the assembly to conform to the flat bottom plate at the cycling temperature. Stress relieving is accomplished simultaneously with flattening. To obtain the mild steel plates large enough to sandwich the titanium plate, it was necessary to weld two plates together to make one flattening plate. The final size of the two flattening plates is 3 by 108 by 200 inches. The weight of each is approximately 20,000 pounds. One side of each plate was machined to a tolerance of $\pm$ 0.020 inch with a 125 RMS finish. Additional weight of 20,000 or more will be placed on top of the sandwich before the hot flattening operation. This additional weight will give us more flattening capability. One mild steel plate will have a hole cut in it to accommodate the ring that has been diffusion bonded to the titanium plate. This method of flattening titanium has been used successfully in the past by Boeing.

Diaphragm

Three diaphragms have been fabricated for the Vacu-form tool. The diaphragms were made by welding together seven sheets of 304 stainless steel 0.020 by 36 by 144 inches. The final size of the diaphragms is 0.020 by 252 by 144 inches. The diaphragms will be used to cover the Vacu-form die with the gore part in the die so that a vacuum can be pulled to form the gore. The diaphragm is clamped to the flange provided on the Vacu-form die.

Diffusion Bonding Tool

The diffusion bonding tool developed and fabricated in Phase I is ready and will be used in Phase III.

Gore Segment Flat Pattern Development

Background

Pocketed, double contoured parts such as the titanium gore segment can be produced by either of two basic methods; machining the pockets (1) in the flat prior to forming, or (2) in the double contour after forming. Either conventional or chemical milling can be considered for both methods. Normally, conventional milling after forming requires 5-axis numerical control to meet tolerances.

For this specific part, conventional milling offered a major cost saving over chemical milling, and the decision was made to pocket the part conventionally. This dictated machining in the flat prior to forming, since Boeing does not yet have 5-axis NC milling equipment large enough to accept the formed part.* The problem remained of

*Nor does any known manufacturer at this time have such equipment. Boeing expect delivery of a 5-axis NC mill in March, 1966, however, which would readily handle a gore of this size and shape.

describing a flat pattern which, when formed, would fall within drawing tolerances.

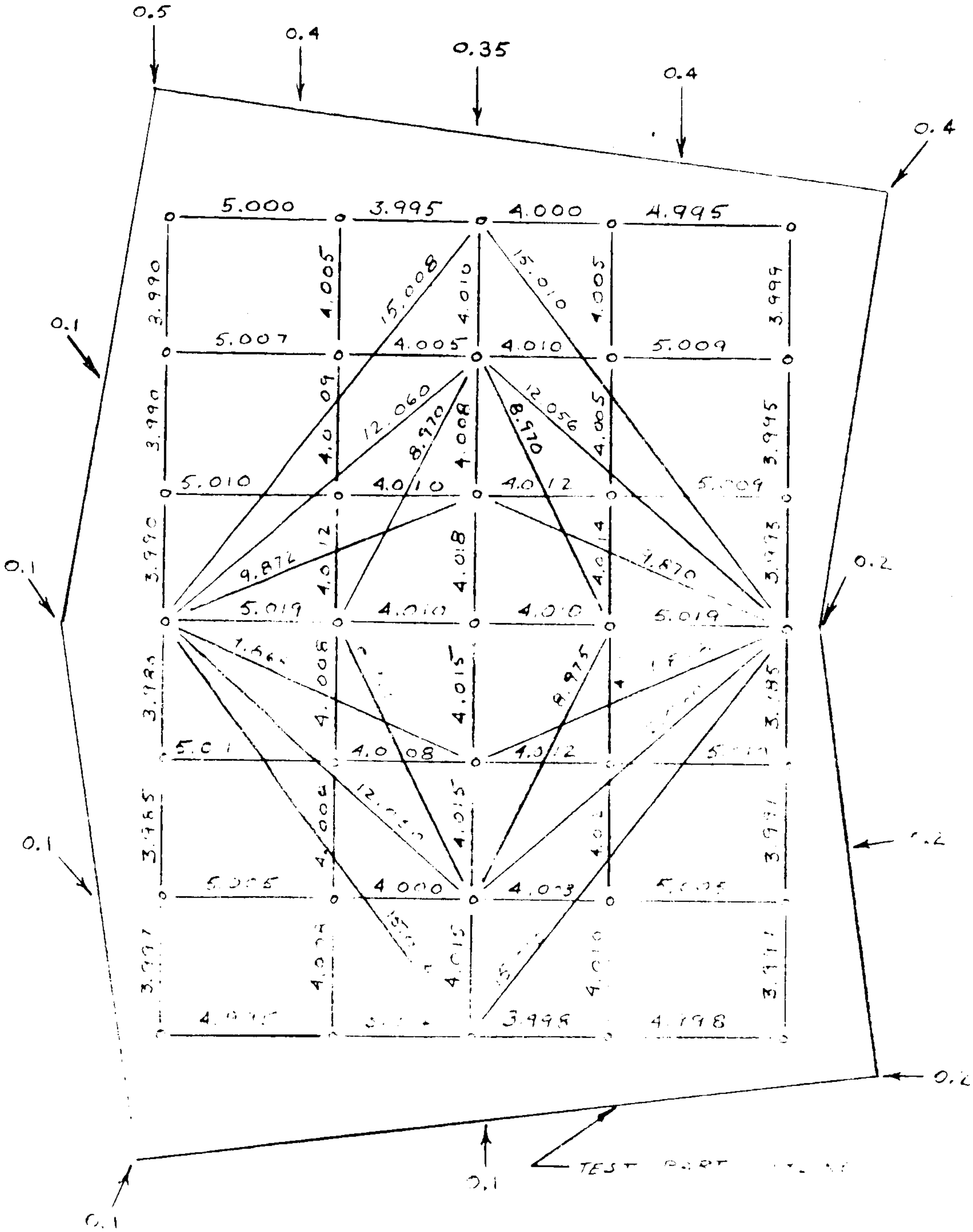
Flat machining patterns for aluminum gores now in production were developed empirically some time ago. Prints of these patterns were obtained and studied. The aluminum gores are hydraulically bulge formed, however, while the titanium gores will be vacuum creep formed. During bulge forming, the entire part stretches, while essentially no material flow results from vacuum creep forming. This difference in forming methods meant the earlier flat pattern work was not applicable.

Since the contract does not provide for the time or material to develop a new empirical flat pattern, analytical methods for applying subscale test results were worked out. The following discussion describes this analytical flat pattern development.

Subscale Tests

A subscale part of nominally 24 by 36 by 1/8 inch was cut into the approximate expected shape of the flat pattern. It was scribed with a 1-inch grid on the side which was to be convex. The accuracy of the grid was about ± 0.001 inch.

Prior to forming (in the same die used for the full-thickness subscale forming tests), the part was leveled in the die and its edges were projected down onto the die surface. A pencil mark was made connecting projected points. After forming, the edge of the part was traced onto the die, and rough measurements were made between the two lines. These measurements are shown in Sketch 1 around the edge of the part, the accompanying arrows indicating the approximate direction of motion. Other figures on the sketch represent measurements between selected points on the formed part. These measurements were made using a flexible steel scale along the curved part surface. Their accuracy is about ± 0.005 inch.



All figures in inches.
All measurements taken along compound contoured surface.

SKETCH 1

SUBSCALE TEST RESULTS

The following conclusions can be drawn from these data:

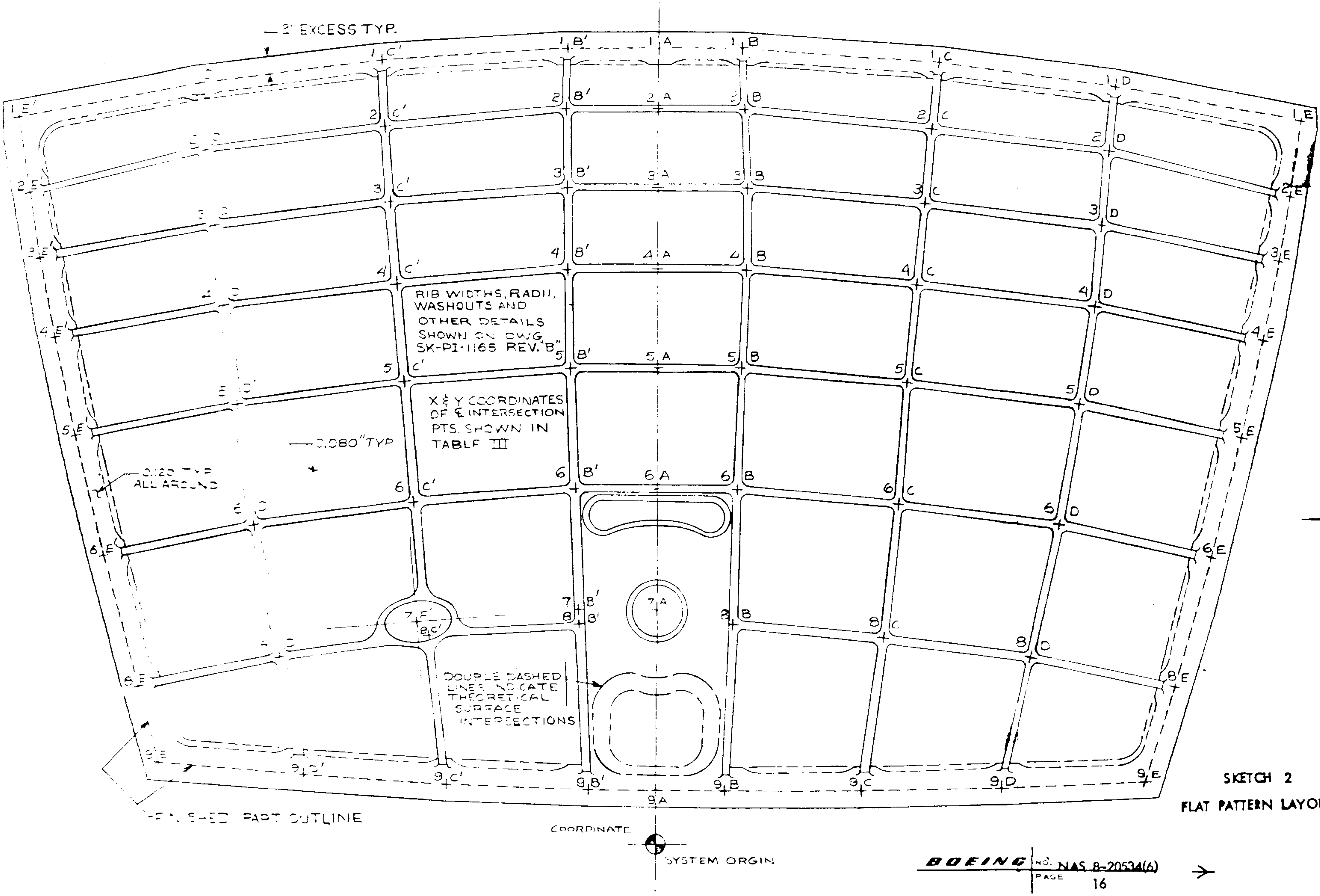
1. The part moved down unsymmetrically, but not enough to materially affect curve tolerances.
2. Points along the centerline of symmetry moved essentially straight down; ie., points originally in the centerplane of part symmetry remained in that plane, or nearly so, during the forming process.
3. Similarly, points essentially along the perpendicular bisector of the centerline of symmetry moved straight down, or nearly so.
4. Lines near the center of the part grew slightly.
5. Lines near the edge of the part shrank slightly.

Within the measuring tolerances of $\pm$ 0.0035 inch, the amounts of growth and shrink exhibited by the subscale part can be expected to occur in the full-scale part. Further, since no major dislocation of grid lines occurred, the distances between rib intersections on the flat, milled blank must equal the arc lengths between rib intersections on the formed part. These arc lengths were determined analytically and modified by scaling up the growth and shrink factors observed in the subscale test.

Based upon the above data, tables were made of the following items:

1. Space coorinates of significant points on the outer gore surface.
2. True length data.
3. X-Y coordinates of the flat pattern.

All the data is available to proceed with the machining of the part in Phase III. All the data developed will become a part of the final report. The flat pattern layout is shown in Sketch 2 with the excess allowance, rib widths, and web thicknesses included to make the flat pattern layout complete.



SKETCH 2

FLAT PATTERN LAYOUT

III. Facilities

Two 75 KVA, 480 volt, 3-phase power carts were purchased with Boeing funds and a third power cart was available within the Company. All three power carts were used during the heatup and proof testing of the Vacu-form tool. See Figure 10. Each console consists of three 25 KW single-phase transformers wired into delta three-phase and six control instruments together with all the necessary electrical components and accessories. Each of the power carts is wired to provide a three-phase delta output at 240 volts with 10 taps providing voltages between 200 and 300 volts. This provision will let us increase or decrease the voltage for the different length tubular heating elements as is necessary to regulate the temperature of the die. Each power cart has six pair of floy type receptacles at the rear of the cabinet. These connect power to six heating zones of the die, therefore, we have capacity for eighteen heating zones in the die. We will only use 16 heating zones.

Each cart contains six instruments with electrical cold junction compensation, bridge-type thermocouple break protection, and adjustable lead length compensation. Each instrument will independently control the temperature within a single heating zone in the die. The scale range of each instrument is 0 to 2000° F. A thermocouple Jack-Panel is installed at the rear of each cabinet. This Jack-Panel will hold six receptacles, each numbered to correspond to the connected control instrument.

The power carts were manufactured by the Tierney Electrical Manufacturing Company, Seattle, Washington. The power carts have proved very satisfactory to date.

IV. Manufacturing Plan

The contract requires that a detailed manufacturing plan for the fabrication of the full-scale titanium gore segments be submitted to NASA for approval at the end of Phase II. This also includes, in detail, the planned inspection and test evaluation programs. The

Manufacturing Plan is in three parts, Receiving Inspection of Titanium Plate, Fabrication of the Gore, and Destructive Testing. A description of each of these three plans is as follows:

A. Receiving Inspection Plan

The Receiving Inspection Record (RIR) will include all inspection and non-destructive test requirements for receiving material. The three titanium plates for the gore segments are being purchased from Titanium Metals Corporation per Boeing document D6-6051-1. The supplier will furnish a report of the results of tests which show conformance to the requirements of the document D6-6051-1. A copy of this report will be submitted to NASA during Phase III of the contract. Our RIR will include the following test results which will be submitted along with supplier's report to NASA during Phase III.

1. Visual and Dimensional Inspection
    a. Packaging and damage.
    b. Marking and identification.
    c. Dimensional requirements.
    d. Straightness and/or flatness.

2. Chemical Lab
    a. Chemical analysis - emission spectroscopy.
    b. Gas analysis - hydrogen, oxygen, nitrogen.
    c. Chemical analysis - carbon.

3. Physical Test
    a. Tensile properties - uts, yts, elongation.
        (1) Longitudinal
        (2) Long transverse
    b. Bend test.

4. Met. Lab.

    Macrostructure examination

5. Ultrasonic

Class A, BAC 5439.

B. Fabrication Plan

The manufacturing plan for fabrication of the gore is shown in detail in the Manufacturing and Inspection Record (M & IR) which is a part of this report. In general the plan is as follows:

1. Obtain raw material after Receiving Inspection has been accomplished.
2. Machine reinforcing ring with excess.
3. Trepan rough hole in titanium plate.
4. Clean for diffusion bonding.
5. Diffusion bond ring to plate.
6. Clean and coat part for hot flattening.
7. Hot flatten part in furnace.
8. Clean.
9. Machine pockets in the assembly.
10. Clean and coat for forming.
11. Hot Vacu-form.
12. Clean.
13. Trim to final size and finish machine the fitting hole (identify and note location of excess material in relation to the part).
14. Make specimens from excess material from formed part for testing.
15. Submit specimens to Engineering or Quality Control as applicable for testing per Test Plan.
16. Test specimens of one formed part will be submitted to Engineering or Quality Control as applicable for destructive tests per the Test Plan.
17. Two formed parts will be submitted to NASA.
18. During the fabrication each applicable operation will be inspected by Quality Control as will the finished gore segment. For the detailed manufacturing plan see the M & IR paper included as part of this report.

C. Test Plan

Both nondestructive and destructive test requirements for the base gore segments are outlined. Nondestructive tests will be required for all three segments fabricated in Phase III. Only one gore segment wil be destructively tested. The remaining two segments will be delivered to NASA.

Nondestructive Testing

1. Ultrasonic

The raw plate stock from which the gores are to be fabricated shall be ultrasonically inspected per BAC 5439, Class A. The ultrasonic inspection is included in the Receiving Inspection Plan.

2. Penetrant Inspection

The gore segments shall be cleaned and penetrant inspected per 60B32002 after final machining and after hot forming. This will make it possible to isolate whether any discontinuities detected are created during the machining or the forming processes. The penetrant inspection is a part of the manufacturing plan.

Destructive Testing

1. Trim Material

Three sets of tensile test specimens will be taken from the trim material of each gore assembly from three different locations. The approximate locations of the six specimens (three each circumferential and meridional) are shown in Figure 19. Specimens will be tested in accordance with Fed. Test Method No. 151a, specimen type F2, to determine the ultimate tensile strength, 0.2 percent offset yield strength, and elongation in a 2 inch gage length. Each specimen will be identified as to the exact location from which it was taken. Details of specimen preparation are shown in the M & IR paper. The test results will be included in the final report of the contract.

2. Base Gore Assembly

a. Mechanical Properties

Test specimens for the evaluation of mechanical properties of a completed gore shall be taken from the locations shown in Figure 20. Each specimen will be identified as to its location. The specimens will be tested per Fed. Test Method No. 151a, to determine ultimate tensile strength, 0.2 percent offset yield strength, and elongation. For the diffusion bond joint specimens, the gage length shall be 0.25 inch and other dimensions shall be the maximum attainable using the same proportions as the type R5 specimens in Fed. Test Method No. 151a.

b. Metallography

Specimens for metallographic examination will be obtained from the locations shown in Figure 20. Each specimen will be examined in the three principle grain directions and 10X and 100X photographs of each grain direction will be supplied. These photos will be compared to photos of as received plate material to show any changes in microstructure during processing.

c. Chemical Analysis

Chemical analysis of the completed assembly will be checked spectrochemically in accordance with Fed. Test Method No. 151a.

d. Hydrogen Content

An analysis for hydrogen content will be performed per Boeing Document D2-1752.

e. Physical properties will not be significantly affected by the manufacturing process and no physical property tests are to be performed.

Details of specimen preparation are shown in the M & IR paper.

Under certain load conditions in an aqueous salt solution, Ti 8-1-1 is susceptible to stress corrosion cracking. Dr. B. F. Brown of the U. S. Naval Research Laboratory has published a draft report in March, 1965, entitled "A New Stress Corrosion Cracking Test Procedure for High Strength Alloys". The test involves steady-state loading of precracked charpy specimens in a 3 1/2% aqueous salt solution. Published test results indicated a reduction in precracked charpy impact resistance.

Boeing has substantiated the small precracked charpy results by correlation with wide center-notched and surface-flawed panels used to determine plain strain and plane stress fracture toughness parameters.

Results of these tests have been submitted to the NASA Committee on Structures for the Supersonic Transport, and are recorded in the Thirteenth Meeting notes. In view of the availability of the above data, no additional stress corrosion testing will be performed in this study.

CONCLUSIONS

All tooling has been fabricated and is in readiness, all materials are available except the titanium plate for the gores, the Manufacturing Plan is prepared and is included in this report, and all facilities are on hand. Other than not having the titanium plate, we are ready for go-ahead for the final Phase III of the contract. Although the three titanium plates for the gores were ordered four months ago they have not arrived. Titanium Metals Corporation has had a problem in the mill rolling of the titanium fillet. The plate was rolled down to a thickness of 2-1/2 inches when micro cracks appeared on the plate surface. The roll operation was immediately stopped. Negotiations are now in progress as to what the next step will be. The supplier believes that if they can machine the plate surface the micro cracks can be removed. They will then reroll the plate at a higher temperature of 1950° F which in their opinion will eliminate further micro cracks. The machining operation will remove enough material so no full size plates can be made. When a definite plan has been made, NASA will be informed so they can advise us of their decision.

VACUUM FORM DIE FOR TITANIUM GORE

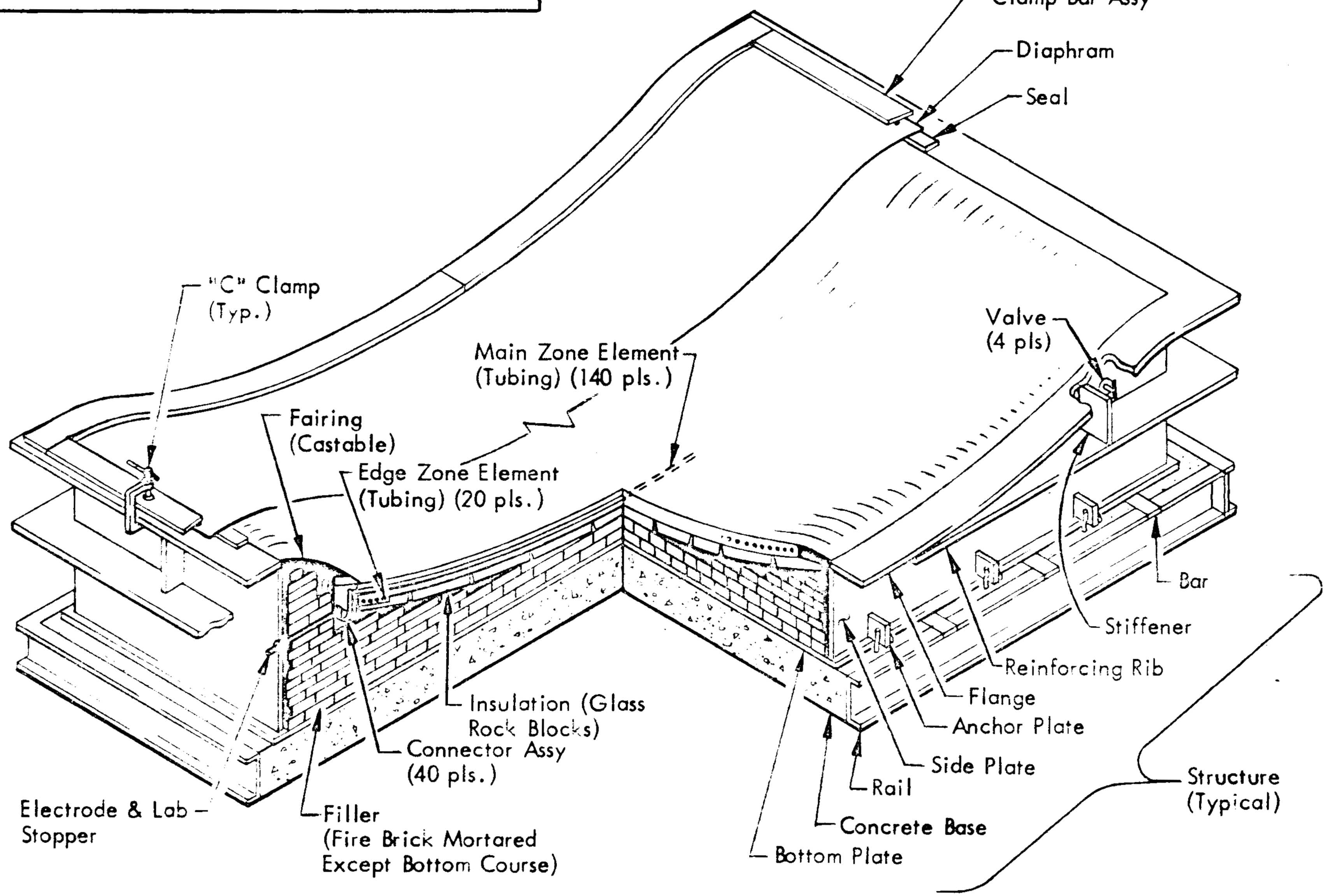


FIGURE 1

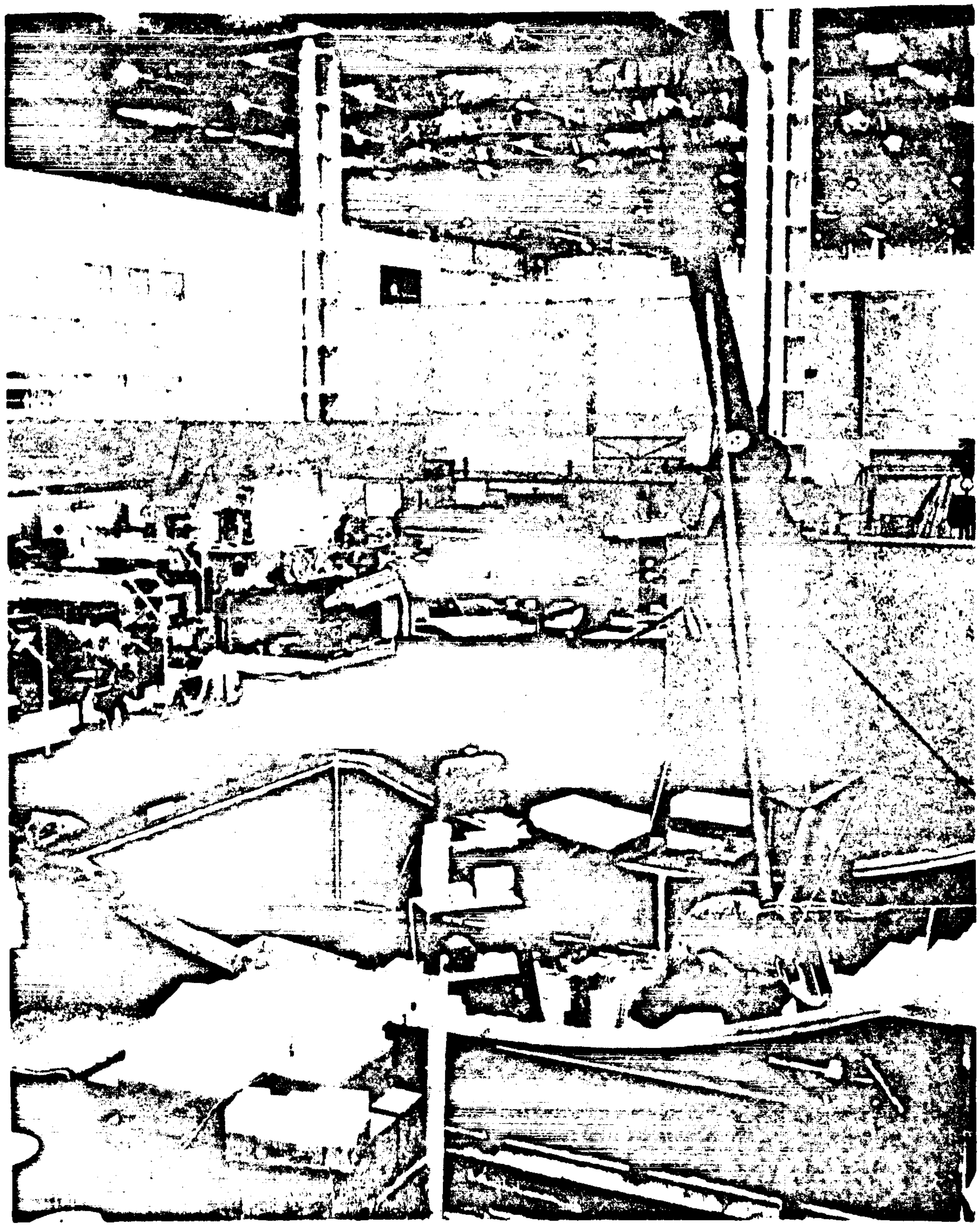


FIGURE 2

INTERNAL CONSTRUCTION OF THE VACU-FORM TOOL SHOWING FIRE-BRICK BEING LAID. THE SCREED TOOL IS BEING USED TO CONTROL FIRE-BRICK PLACEMENT.

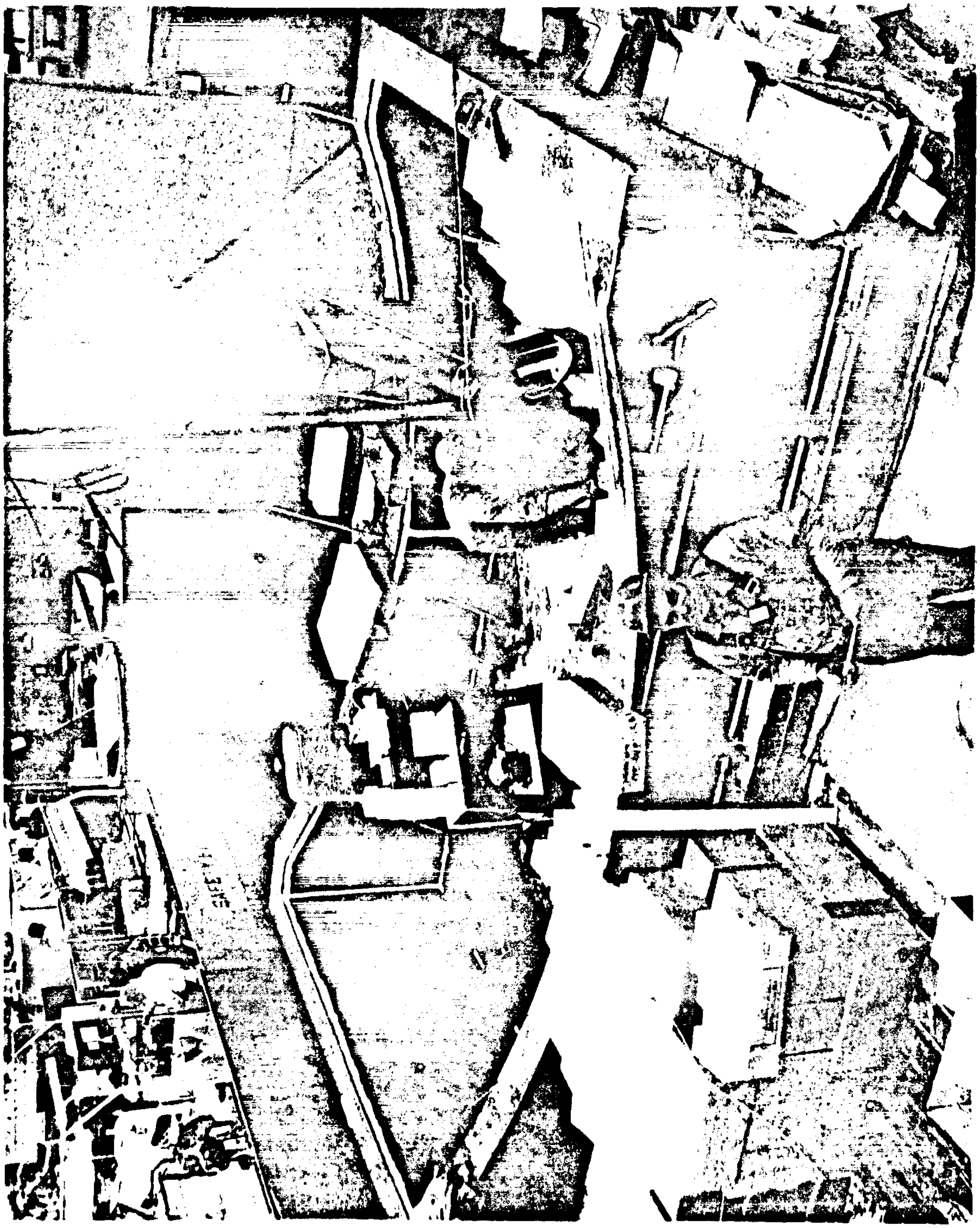


FIGURE 3

VACU-FORM TOOL CONSTRUCTION

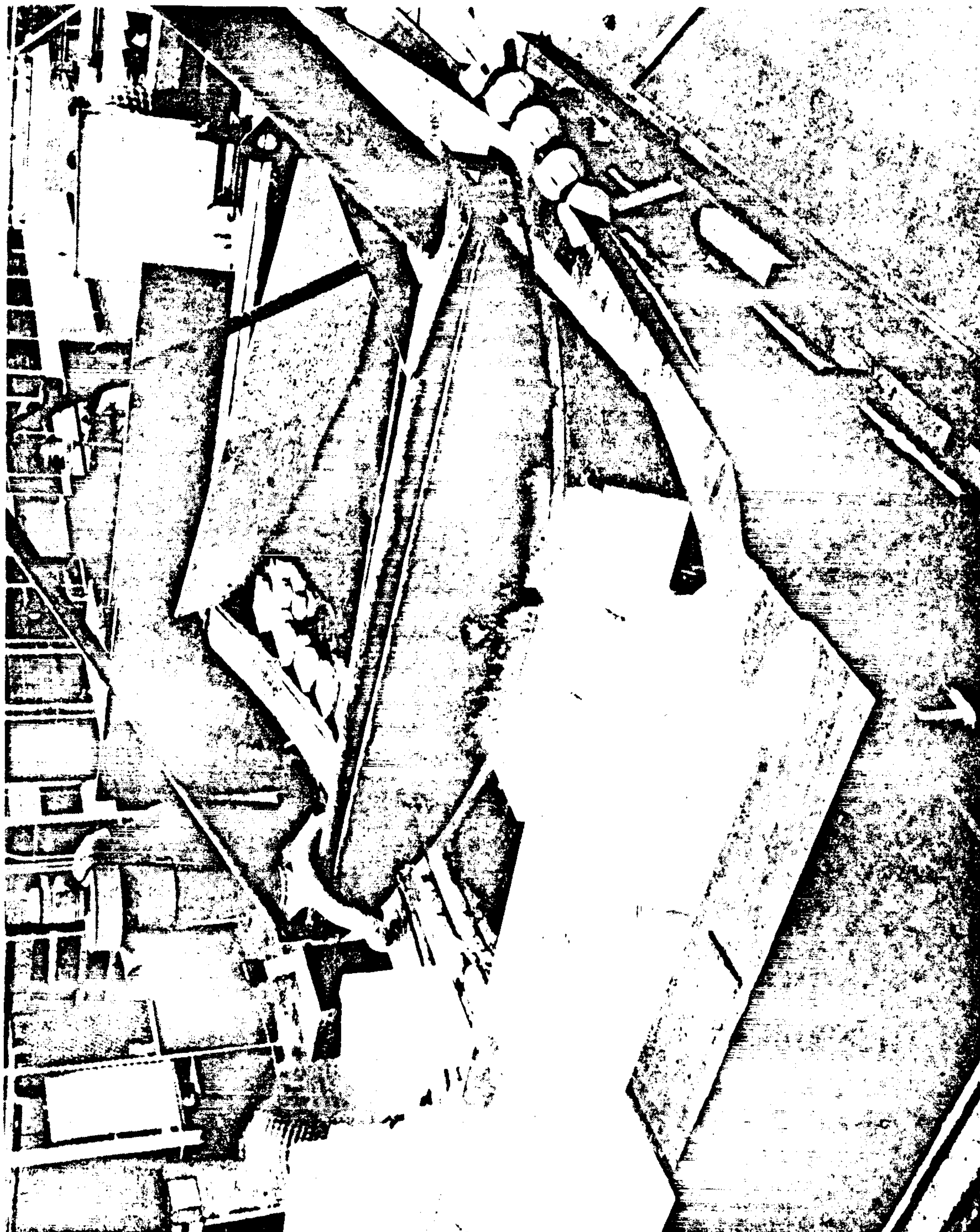


FIGURE 4

VACU-FORM TOOL CONSTRUCTION SHOWING GLASROCK FOAM BLOCKS BEING CEMENTED IN PLACE AND CHECKED BY THE SCREED TOOL FOR CONTOUR.

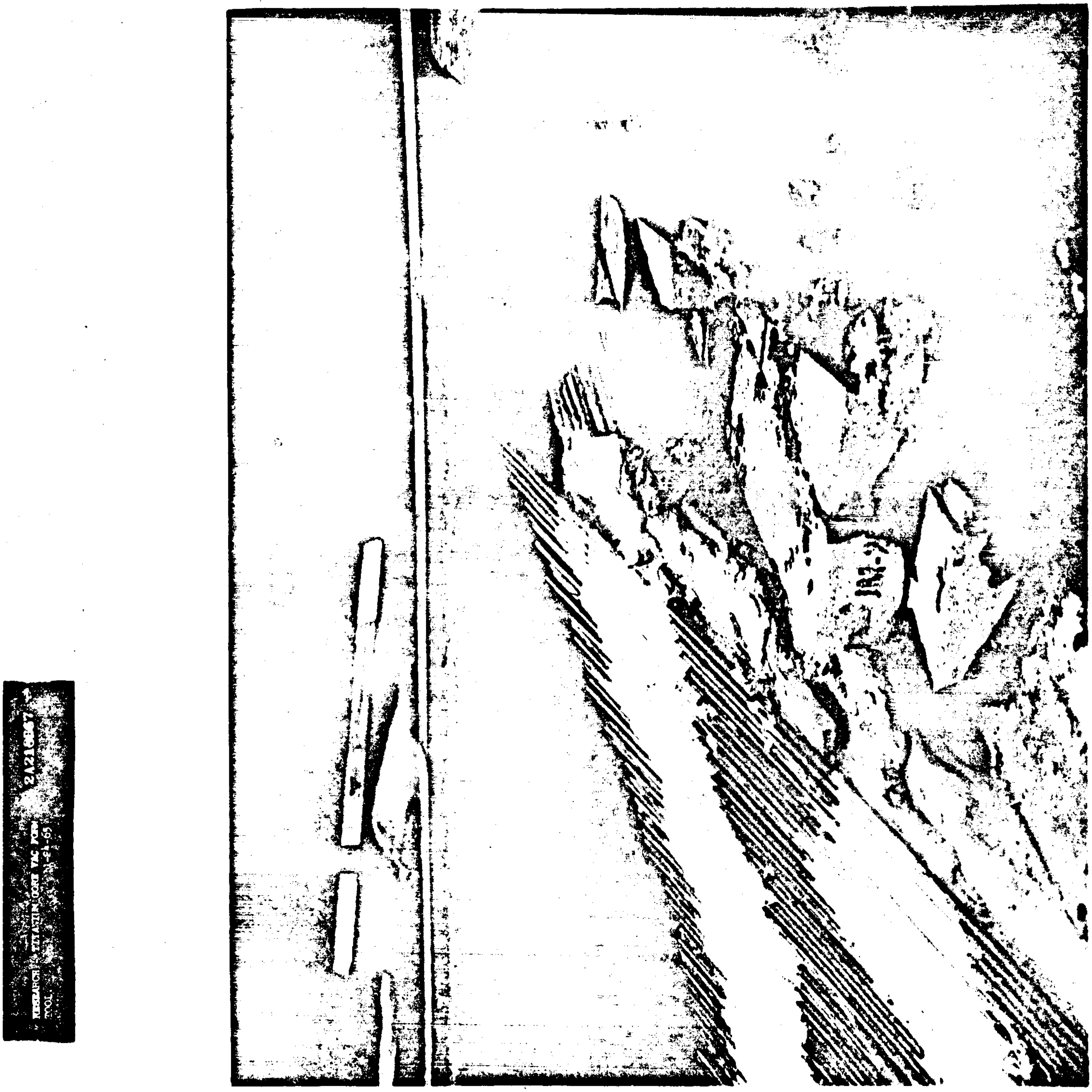


FIGURE 5

A CLOSE-UP VIEW OF THE WAX COVERED HEATING TUBES CEMENTED IN PLACE

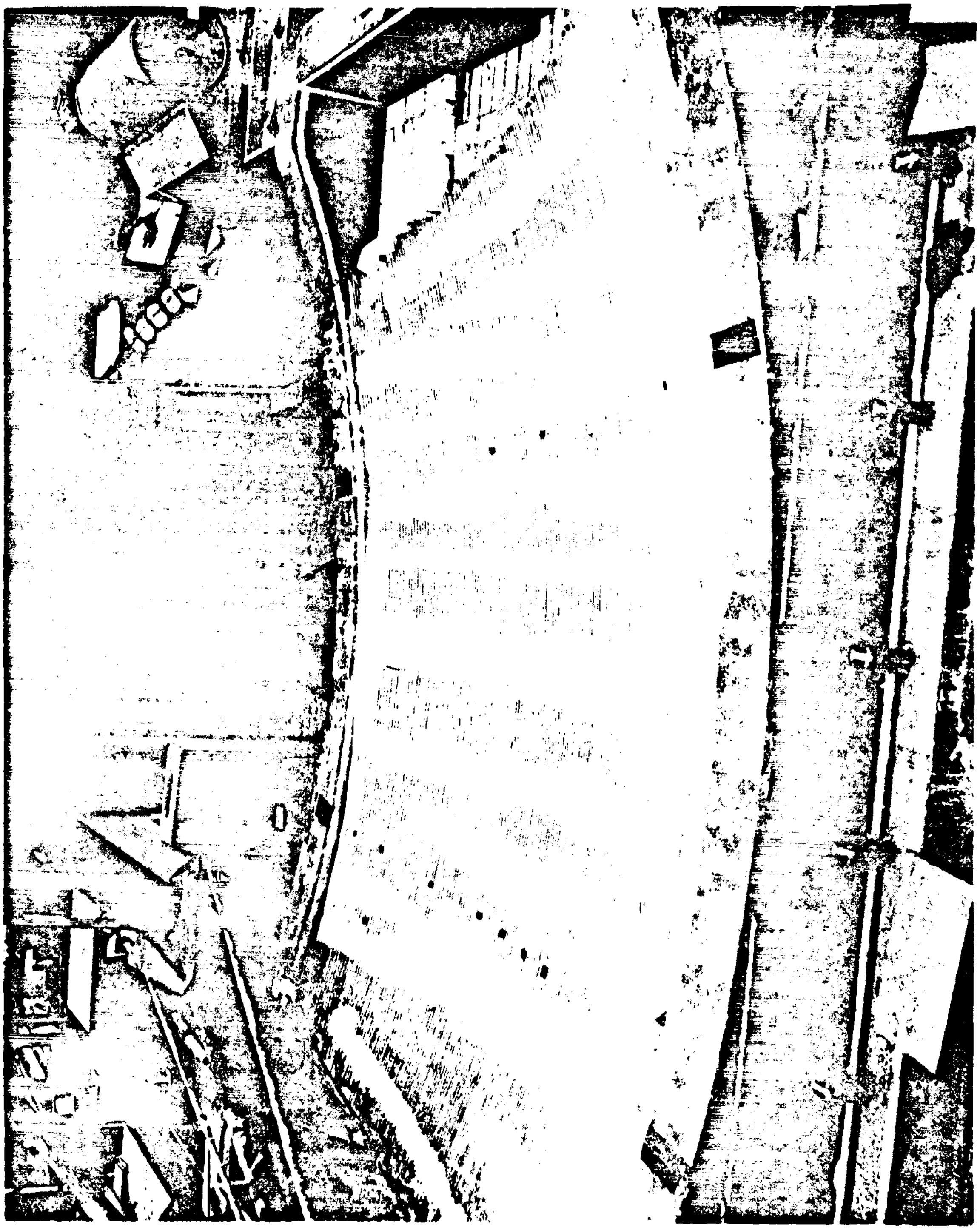


FIGURE 6

THE WAX COVERED HEATING TUBES CEMENTED IN PLACE

2-3930-1115

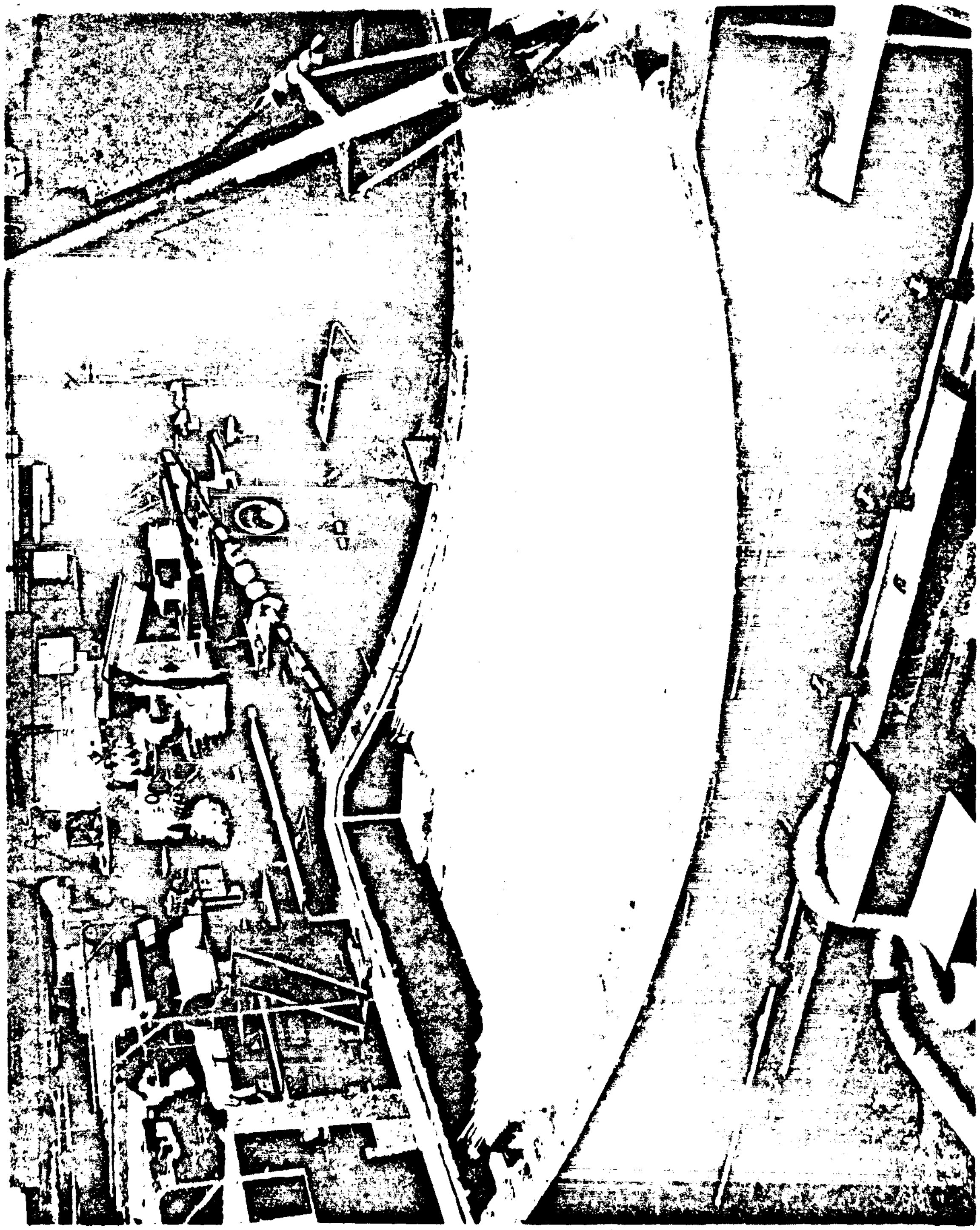


FIGURE 7

FINISHED SURFACE MADE BY SCREEDING A 3/8-INCH COATING OF CEMENT OVER THE HEATING ELEMENTS

RESEARCH - TITANIUM CORE VACUUM FORMING TOOL. 12-6-65 2A219250

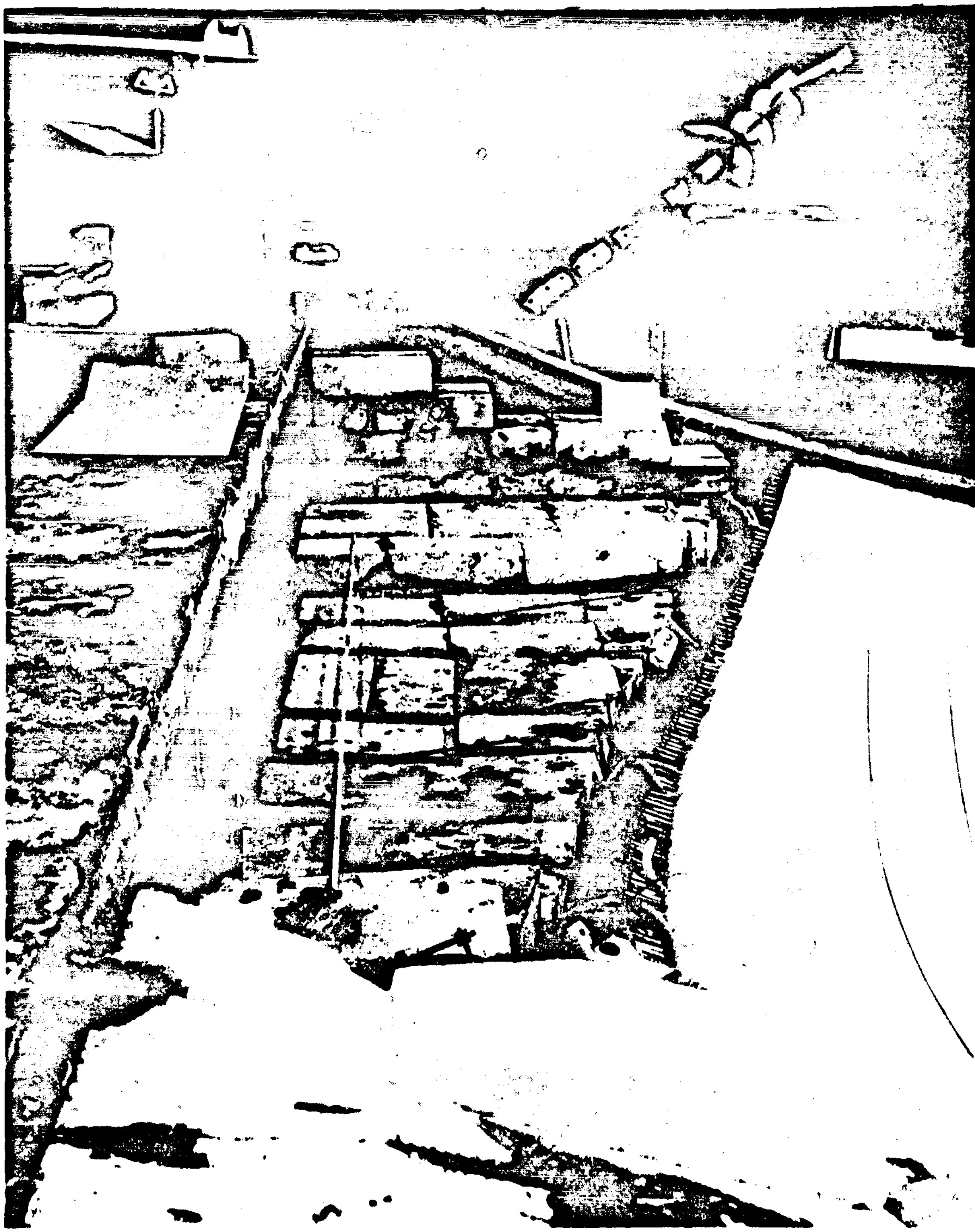


FIGURE 8

STEEL BRAID WELDED TO THE TUBULAR HEATING ELEMENTS IN GROUPS OF 10 ELEMENTS FOR THE ELECTRICAL HOOK-UP

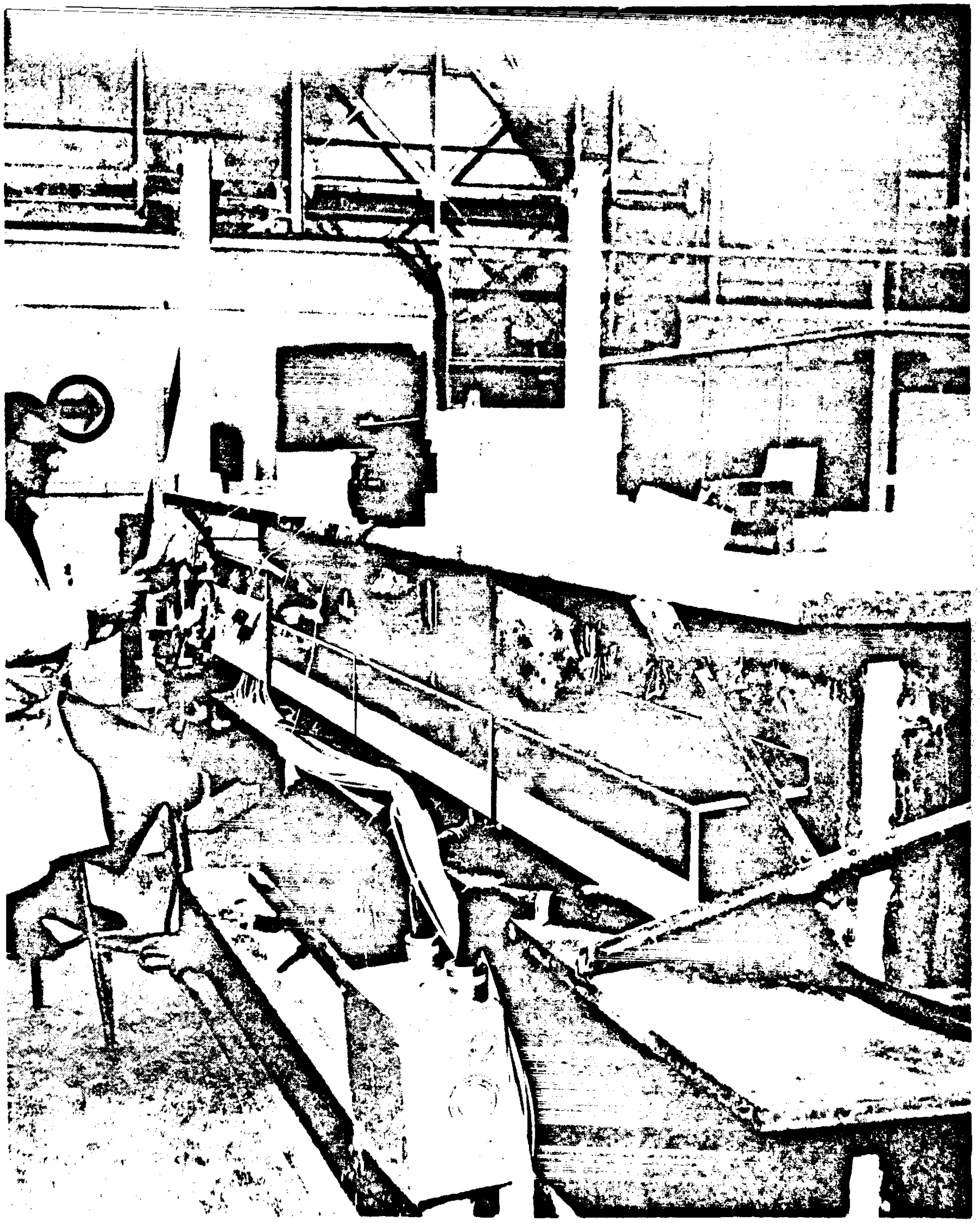


FIGURE 9

CHECKING THERMOCOUPLE CONNECTIONS. COVER PLATES ARE TO PROTECT PERSONNEL FROM EXPOSED ELECTRICAL CONNECTIONS TO THE DIE.

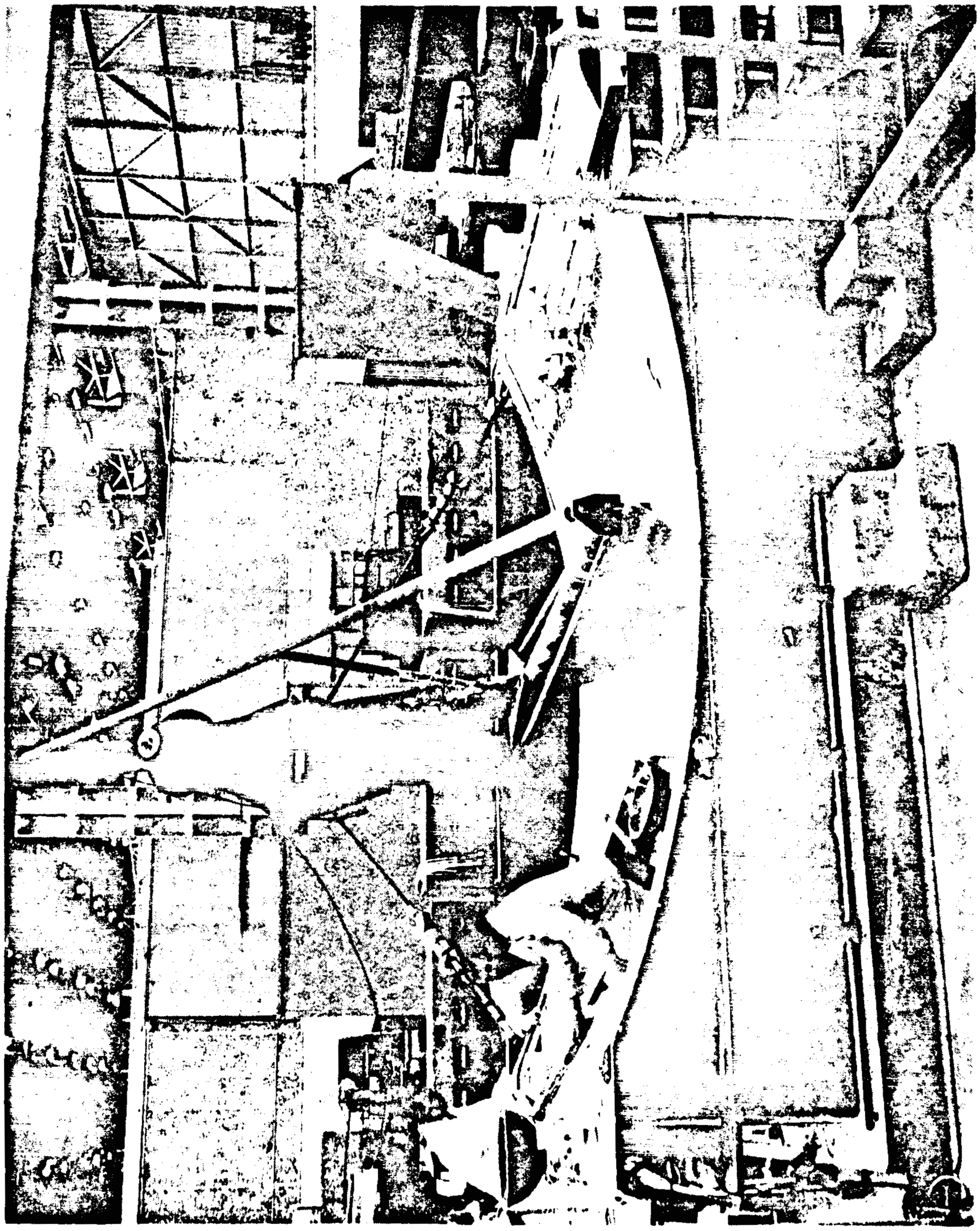
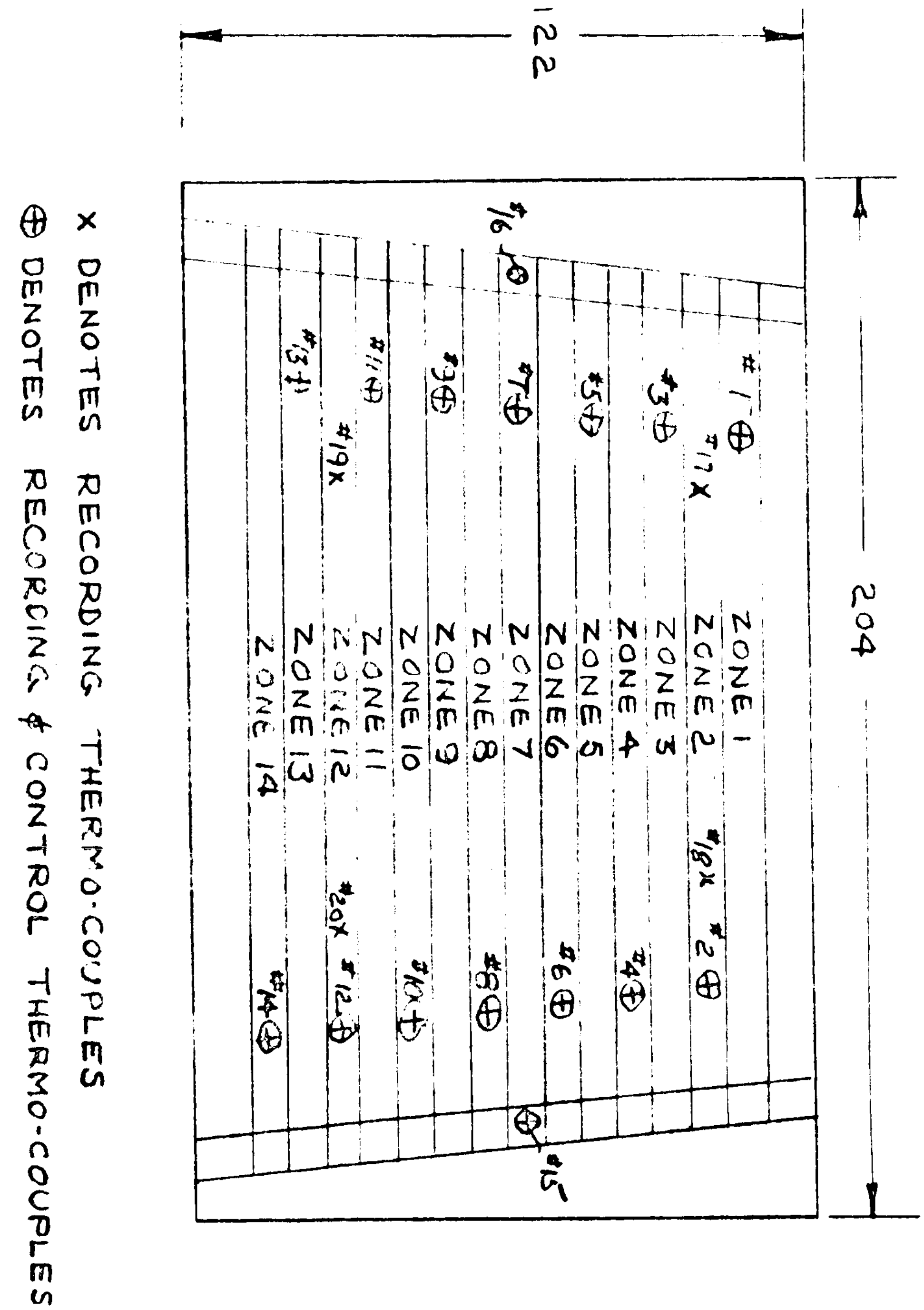


FIGURE 10

CLOSING THE DIE ENDS AFTER THE ELECTRICAL CONNECTIONS HAD BEEN CHECKED IN OPERATIONS. NOTE THE (3) 75 KVA POWER CARTS IN THE BACKGROUND.



	INITIALS	DATE	REV BY INITIALS	DATE	TITLE	MODEL
CALC					FIGURE 11	
CHECK					DIE THERMOCOUPLE LOCATIONS	
APPD						
APPD						

U3 4038 8000 REV 10 64

REV LTR

BOEING NO NAS 9-2033(6)

SH 34

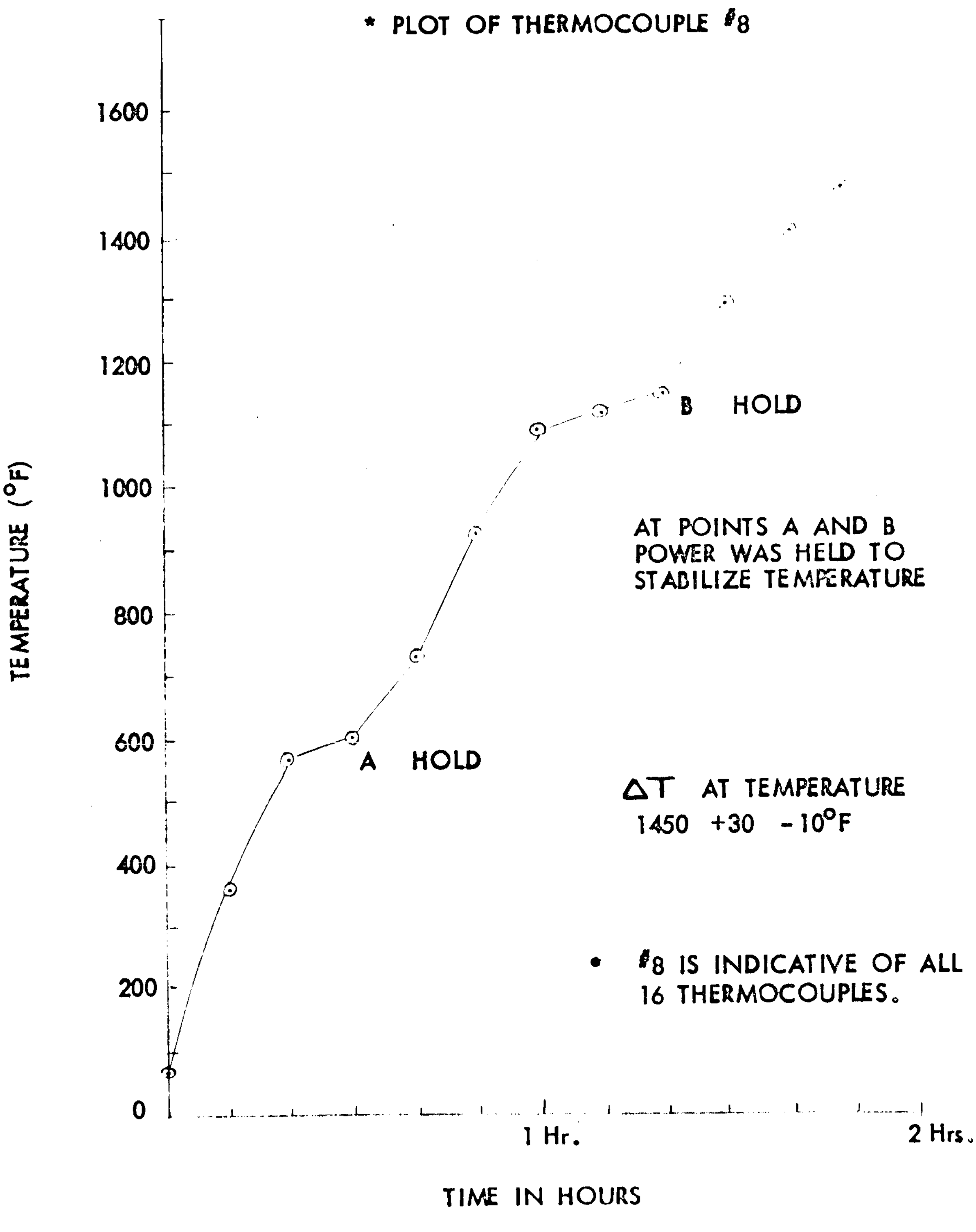


FIGURE 12

HEAT UP CURVE OF VACU-FORM DIE
TEST NO. 1

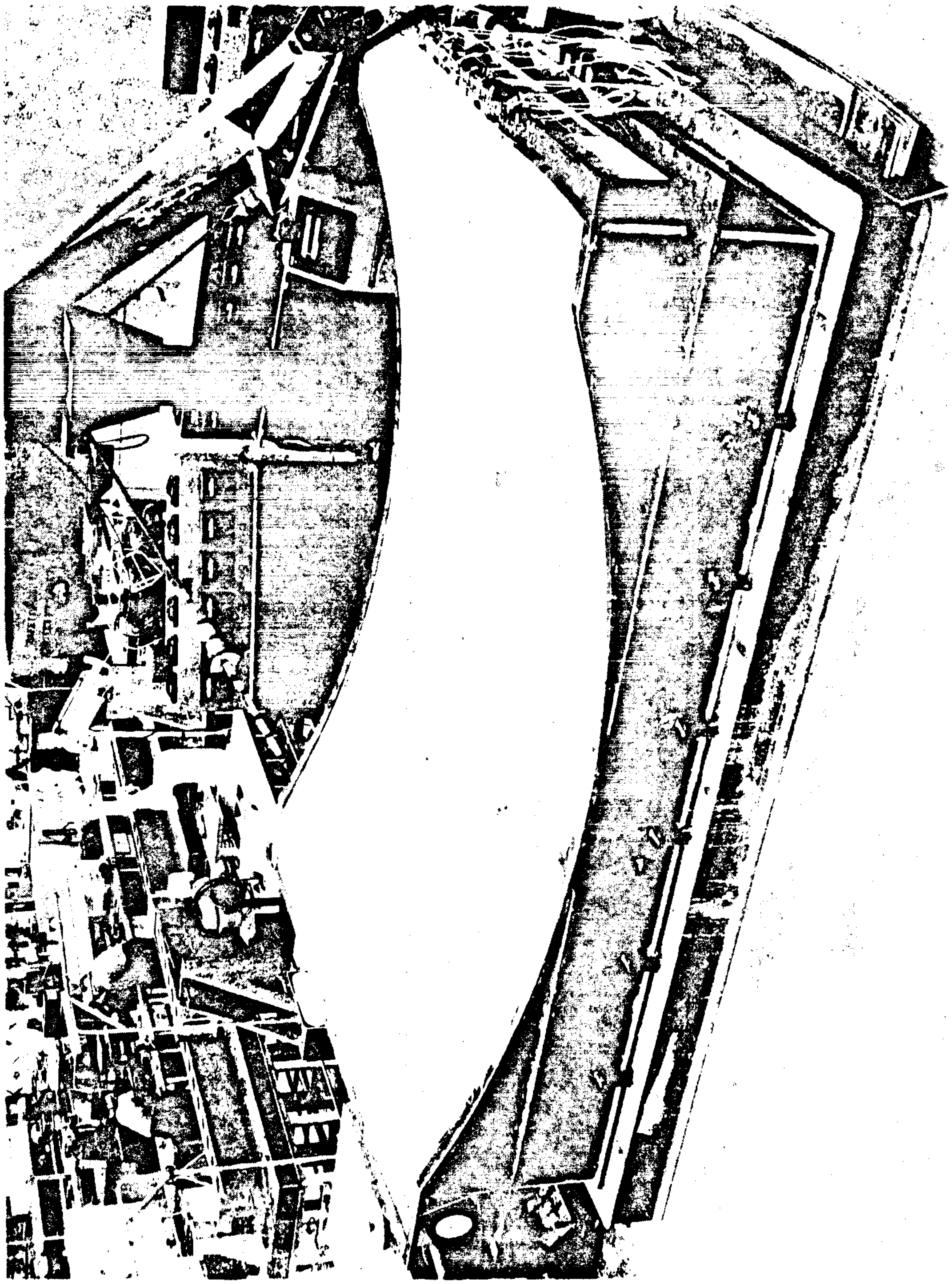


FIGURE 13

THE COMPLETED VACU-FORM DIE WITH A VINYL SHEET IN PLACE DURING A VACUUM TEST

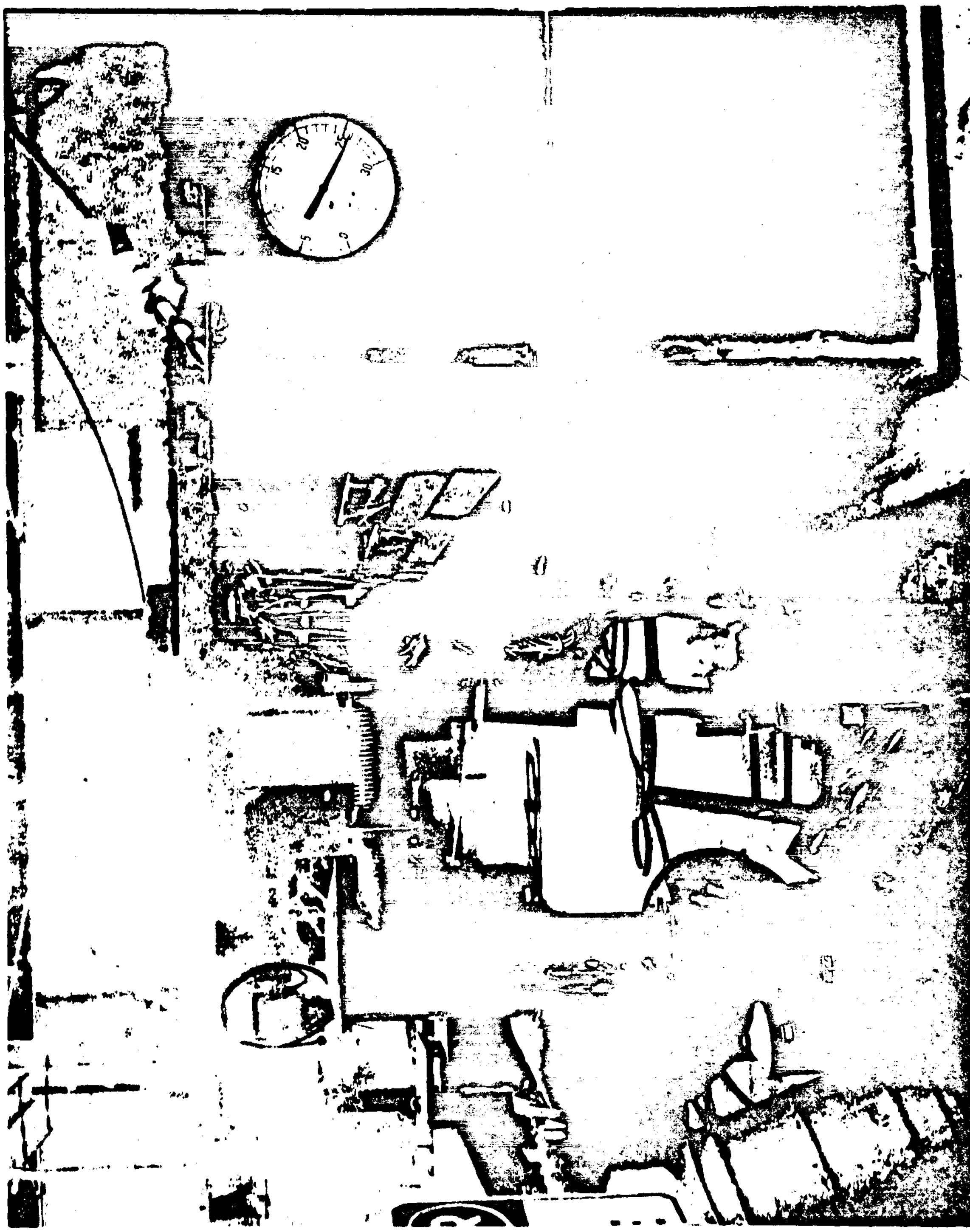


FIGURE 14

A CLOSE UP VIEW OF THE VACUUM PUMP AND METER DURING A VACUUM TEST OF THE DIE. A VACUUM OF ABOUT 26 INCHES OF Hg. IS BEING OBTAINED AS INDICATED ON THE METER.

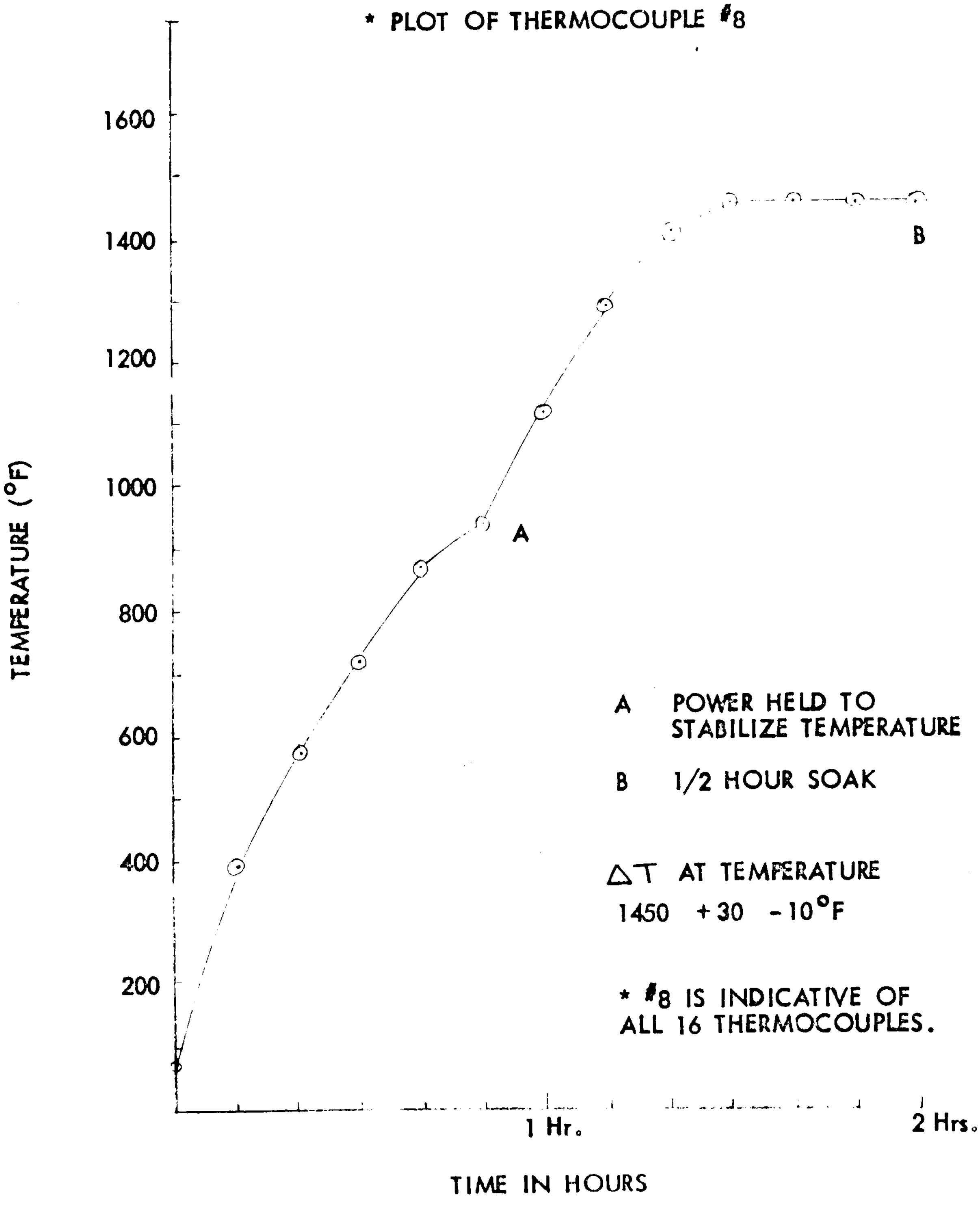


FIGURE 15

HEAT UP AND SOAK CURVE OF VACU-FORM DIE

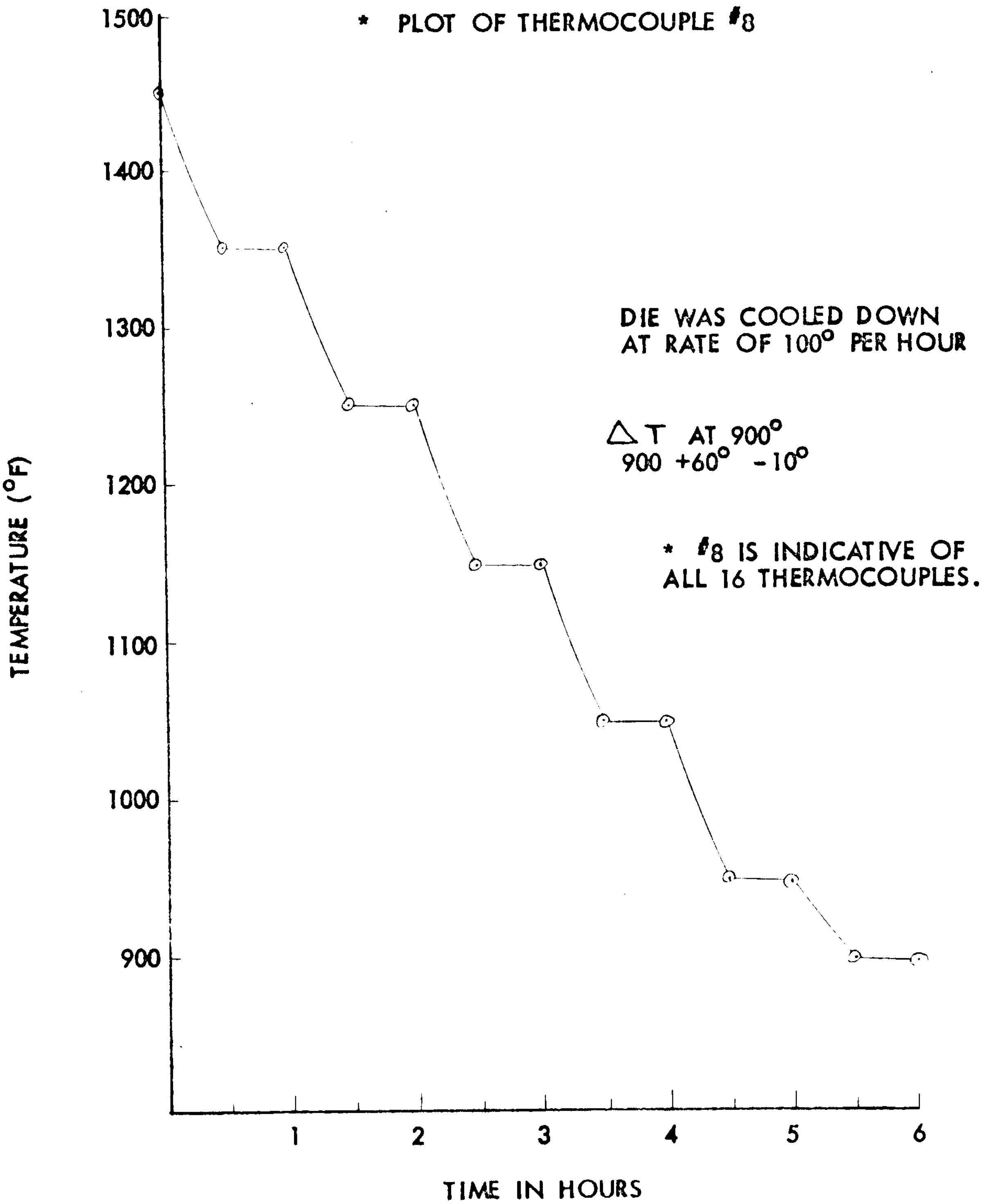


FIGURE 16

CONTROLLED COOL DOWN CURVE OF VACU-FORM DIE

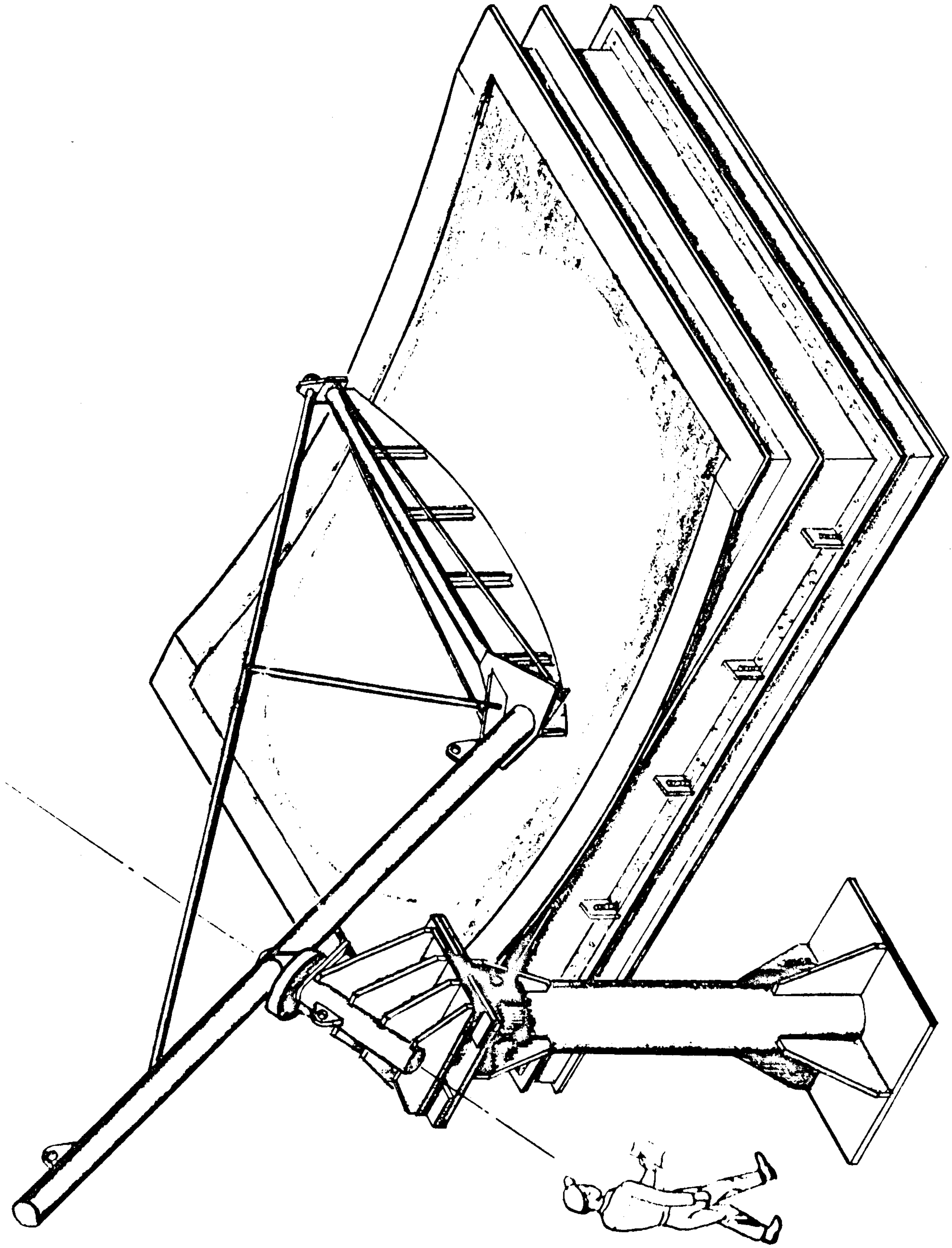


FIGURE 17

SCREED TOOL AND ITS RELATIONSHIP TO THE VACU-FORM TOOL

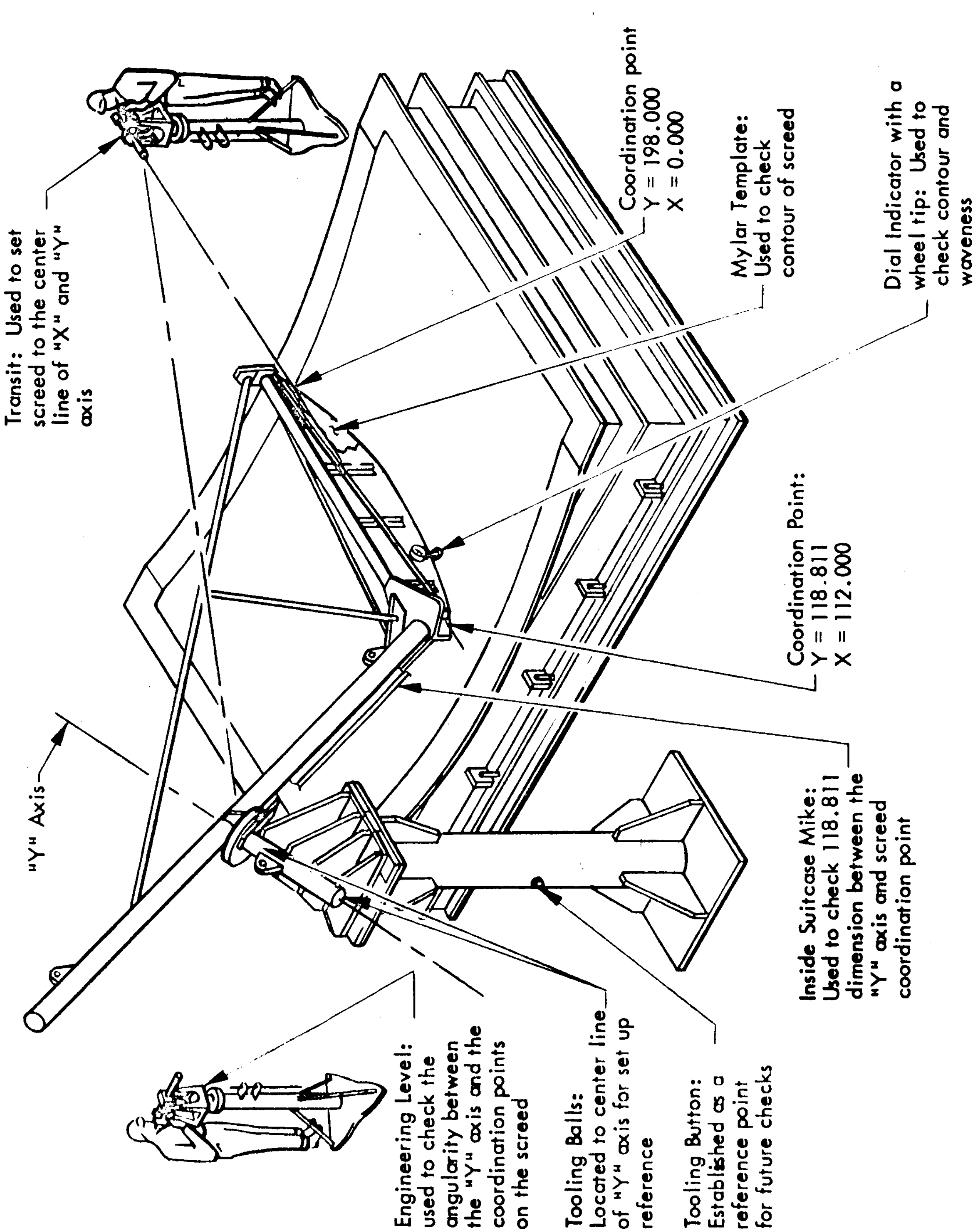


FIGURE 18

INSPECTION PROCEDURE FOR CHECKING SCREED AND VACU-FORM TOOLS

Contract NAS 8-20534 "Research and Development for Fabricating A Simulated Titanium Alloy Gore Segment, Lower Bulkhead, for S-IC Fuel Tank".

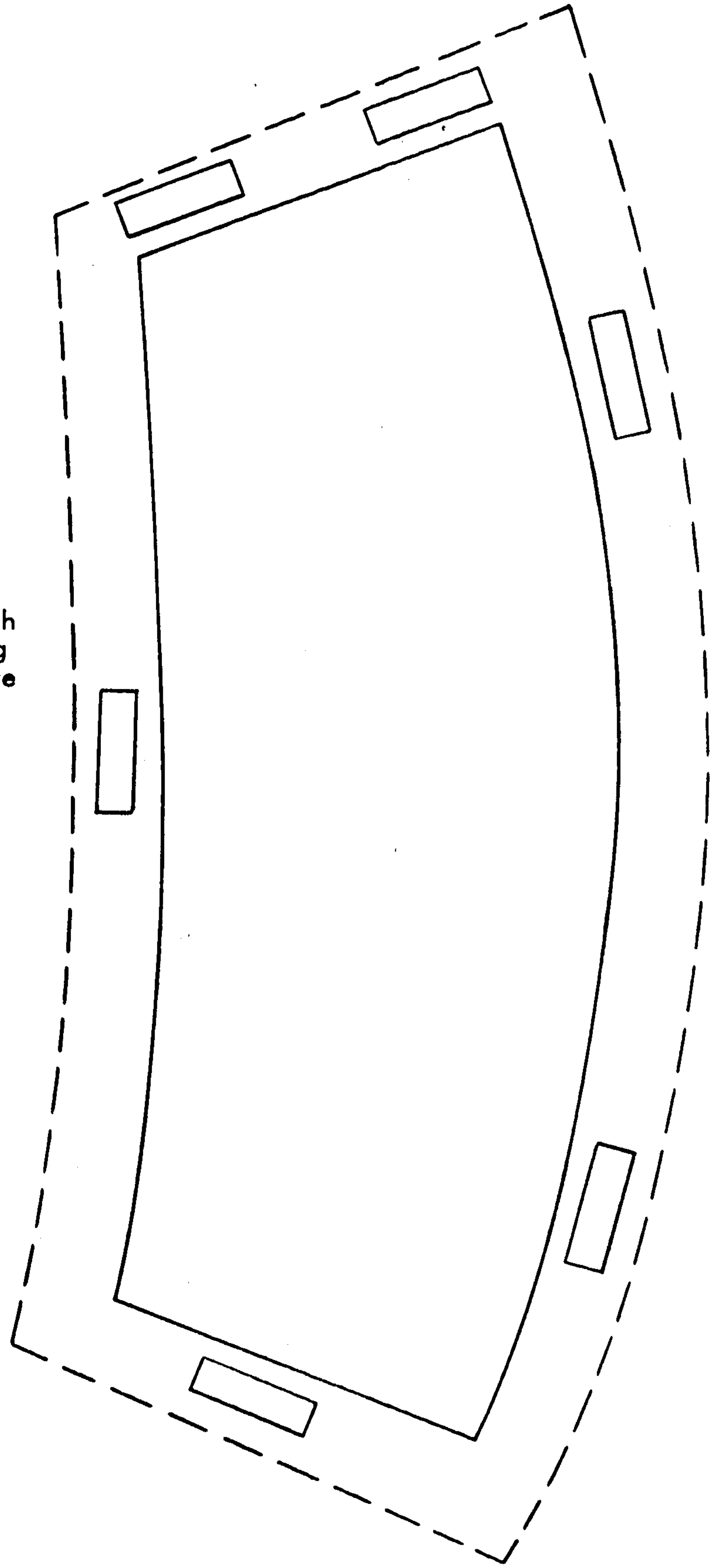


FIGURE 19
TRIM MATERIAL TENSILE SPECIMEN LOCATIONS

Type F_2 specimens (Federal Test Method Number 151A)

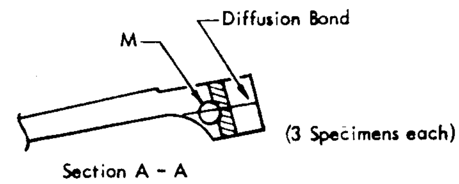
Type R_2 specimens (Federal Test Method Number 151A)*

Type R_5 specimens (Federal Test Method Number 151A)*

Metallographic Examination

* Centerline of round specimens shall coincide with the centerline of the section from which they are taken.

Contract NAS 8-20534 "Research and Development For Fabricating A Simulated Titanium Alloy Gore Segment, Lower Bulkhead, For S-IC Fuel Tank"



Section A - A

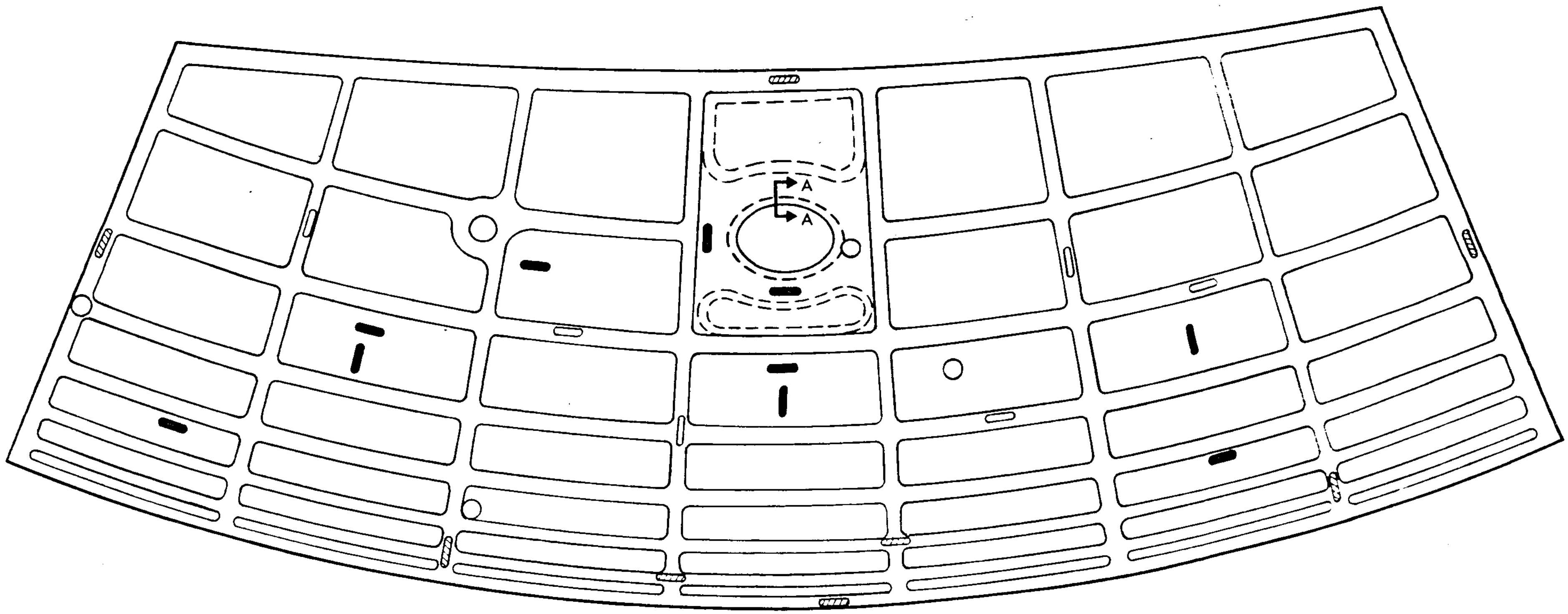


FIGURE 20

TENSILE AND METALLOGRAPHIC SPECIMENS FOR DESTRUCTIVELY TESTED TITANIUM BASE GORE

RESEARCH & DEVELOPMENT FOR FABRICATING A SIMULATED TITANIUM ALLOY BASE GORE SEGMENT, LOWER BULKHEAD, FOR THE S-IC FUEL TANK

NAS3-20534

PERIOD THROUGH DEC 1965